ROBERT A. NORMAN
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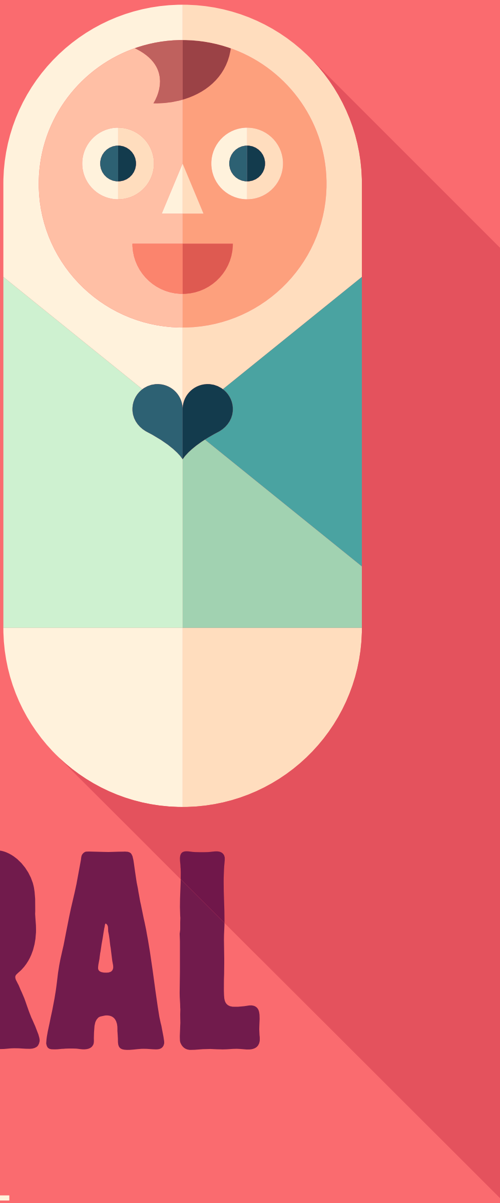
THE LAST NATURAL MAN



WHERE HAVE WE BEEN AND WHERE ARE WE GOING?

Springer

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Robert A. Norman • Sharad P. Paul

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Preface

We are at the crossroads of a major transformation. Why is our current time so important in the history of man? We are at a point where we may be the last generation that is still partially or fully natural.

The last natural man. Natural in what way? What is "natural"? Is it a catch phrase like "integrative" or "holistic" that transmits a certain magical warm glow? If the word "natural" was a plant, it would be beautiful, green, luxuriant, and edible.

Does it mean we are the last to not replace or modify our parts? What about laser surgery? Knee or hip replacement? Botox and fillers? Chemical therapy? Or a directional chip in the brain?

Do we really mean the very last natural man? Cultural evolution has been the major driving force over the last several thousand years and enormous in its influence compared to almost invisible changes in our physical adaptations. If cultural and religious evolution was the driver for human history, are we now entering the phase of physical transformation – where humanity refuses to accept mortality and seeks to make changes to defeat nature?

Ray Kurzweil calls the coming age, "The Age of Spiritual Machines." The full title of Kurzweil's book is *The Age of Spiritual Machines*: *When Computers Exceed Human Intelligence*. Kurzweil has been described as being an evangelist of an amazing future on Earth and hyperbolic scientific optimist. But where are our personal flying machines (as we were also promised watching the Jetsons as children) and cures for all diseases that have been promoted by Kurzweil and others like him? Have the biologic and technical miracles happened yet or live just around the corner? We don't fly one of these machines to our medical practices to make instant diagnoses and cures.

In our book we are describing a paradigm shift of all of humanity – just as hunter-gatherers had their stellar features, the future man will have many attractive qualities, even if many artificial. We are often balancing on the precipice between science and science fiction, now ready to tip the scales and slide comfortably into the future of great discoveries and wonderful changes. But are these changes all for the good? What will being human mean?

Many crucial and important questions will be addressed in the pages of our book, including: What are the true medical and social problems facing us? Which are the highest value targets we need to focus on to ensure our best route of success? How can we protect our futures and enhance our lives by understanding what it means to be the "last natural humans" to roam this planet?

The historian Yuval Noah Harari, in his book *Sapiens*: *A Brief History of Humankind*, writes about cyborg engineering. As he notes, "Cyborgs are beings which combine organic and inorganic parts, such as a human with bionic hands. In a sense, nearly all of us are bionic these days, since our natural senses and functions are supplemented by devices such as eyeglasses, pacemakers, orthotics, and even computers and mobile phones (which relieve our brains of some of their data storage and processing burdens). We stand poised on the brink of becoming true cyborgs, of having inorganic features that are inseparable from our bodies, features that modify our abilities, desires, personalities and identities."

Medicine is littered with organisms, symptoms, and diseases marching together in a cavalcade, their arms linked, surging down the evolutionary path. In between the covers of this book, we combine our fascination with the history of medicine, evolutionary biology, and medical anthropology and mix it with modern medicine and science to investigate how we evolved and where we are headed.

Despite all of the forces that seem to be stopping our progress in making our best decisions to prosper, including political stalemates, global warming, and uncontrolled greed, we consider this a time of hope and that the ideas set forth in our book can be, overall, quite optimistic. But the tough mission of reform and revision will not be accomplished if we do not all join forces to help. We are hoping this book will be a clear and engaging guidebook for navigating the often confusing and cloudy waters of the future of medicine and our life on Earth. Here we will cover the battles we need to face in order to survive and thrive.

Come and walk with us on the journey – the walk of the last natural man.

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Chapter 1

A History of Disease and Human Invention

> Men make use of their illnesses at least as much as they are made use of by them. Aldous Huxley

The history of disease is as old as mankind itself. William McNeill, in his book *Plagues and People*, researched and described the effects of disease on the human race over the entire sweep of human history, from prehistory to the present, and the enormous role and impact disease played in shaping the history of all humanity.

How have we attempted to survive the medical problems and diseases of our past using our natural inventiveness? We often find invention most amazing, and often the pinnacle of human creativity. Many of us have grown up reading the creative stories of Isaac Asimov and HG Wells and benefiting from the discoveries of Edison and Einstein, and we are now seeing how their inventiveness has shaped our world and is now coming to greater fruition.

We are an inventive and creative species and need lots of activities to keep us busy.

We develop many games for pleasure after having tested them out at work. Paint ball started by tagging the cows, zip lining by wanting to explore the treetops.

Invention has been a way of life since the first of our species. Perhaps we can be best classified as a race that rides the ebb and flow of invention from one generation to the next. From the wheel to genetic intervention, we have shaped our culture via invention.

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The Chinese wanted to vanquish the Mongols that had taken over their land. By inventing gunpowder and the guns to use it, they took their land back. And then they invented block printing to announce their victory to the world.

What happened next? In 1440, Gutenberg wanted to help get the Bible out to as many people as he could. How could he make that happen? The block printing was too cumbersome, and each book was done one at a time. Gutenberg's invention of moveable type set the world into a whole new direction. Over 50 million books were printed in the first 10 years of the invention.

From Archimedes' first design of a rudimentary rope and pulley system in ancient Greece over 2000 years ago, to Otis' elevator in 1853 that had a maximum lift capacity of four tons, we now have the world's strongest elevator on board the Ronald Reagan supercarrier. The elevator can lift two F8 fighter planes and more—up to 200,000 pounds—from the hanger bay to the flight deck up three stories in height in ten seconds and back using massive load centers that convert nuclear power to electro-hydraulic force.

The list goes on and on. The telephone, the car, the telegraph, the use of atomic and solar energy, the personal computer, the new cell phones.

Right now we are in the most advanced age of computers and rapid communication. How do we process all the information, filter out what is most important for our future, and determine how we can direct the course of our futures? We now acquire information at a head-spinning rate. Since the dawn of civilization until 2003 we had accumulated five exabites; an exabite is 1 billion gigabytes, roughly equivalent to the capacity of 5.1 million computer hard drives. By 2010 we were generating five times more than all of civilization prior to 2003—five exabites--every 2 days. In 2013, the speed is now blistering along at five exabites every 5 min.

In our book, we also step back in time to use it as a springboard for our exploration. Although Leeuwenhoek discovered bacteria, it was two centuries later when Pasteur tied in their existence to disease in Homo sapiens. Incidentally, following his discovery Pasteur suffered from a morbid fear of dirt and infections; he avoided shaking hands for fear of a contamination. Pasteur also helped to create the world in which cleanliness was next to godliness, which has evolved into a religious zeal, displayed incessantly on our television screens, how the death of germs and their byproducts by disinfectants, deodorants, sprays, and cleaning chemicals germs became a religion, proselytized nightly on the television at enormous costs.

In order to find out where we want to go we have to look at what we are made of and what we want to achieve, and then find the best road we will travel to get there. Dr. Oliver Sacks wrote in his New Yorker article "Altered States", "To live on a day-to-day basis is insufficient for human beings; we need to transcend, transport, escape; we need meaning, understanding, and explanation; we need to see overall patterns in our lives. We need hope, the sense of a future. And we need freedom (or, at least, the illusion of freedom) to get beyond ourselves, whether with telescopes and microscopes and our ever-burgeoning technology, or in states of mind that allow us to travel to other worlds, to rise above our immediate surroundings."

Progress pushed along by invention rarely moves forward in a straight line, and is often one step forward, two steps back. However, it does progress, if only at a glacial pace, and sometimes imperceptibly, painfully, and often with a social and moral lag. The American psychiatrist Karl A. Menninger, in his book *Man Against Himself*, attempts to make this point: "When we remember that in the calendar of time 'civilized' human beings are only a few seconds removed from the cannibal and a few minutes removed from the beasts, it will not be surprising to discover that in the unconscious, cannibalism is not yet extinct."

And part of all this angst is based on our nature as humans. When Robert Sapolsky, in his article "Super Humanity" in Scientific American reflects on the fact that 99 % of human history was spent on the open savanna in small hunter-gatherer bands, he adds, "Indeed, those millions of ancestral years produced many of our hallmark traits-upright walking and big brains, for instance. Of course, those wildly useful evolutionary innovations came at a price: achy backs from our bipedal stance; existential despair from our large, self-contemplative cerebral cortex. As is so often the case with evolution, there is no free lunch." He adds, "And when it comes to humans becoming, on average, smarter, taller, and better at athletics, there is a problem: Who cares about the average? As individuals, we want to individually be better than other individuals. Our brain is invidious, comparative, more interested in contrasts than absolutes."

The world of disease has shifted from the acute to the chronic. We have hundreds of millions of people with chronic disease worldwide, and countless maladies than we can ever uncover. Aging and longevity has never taken center stage like it does now, and will be explored here in detail.

Roy Porter, in his book *Blood and Guts*, wrote, "The dread of disease, potential and actual, the pains of acute complaints and long-term ailments, and the terror of mortality number among our most universal and formidable experiences. Religion and philosophy are arguably the products of mankind's efforts to cope, in mind and heart, individually and collectively, with afflictions and death."

We live in a time of a great technological rise, yet our bodies remain fairly similar to 500 or 5000 years ago. However, we now face a myriad of new endocrine disrupters and other antigens that can interfere with our lives. We have an enormous need to understand our natural environment and discover what we can mimic in nature for success, while simultaneously investigating and defending ourselves from the exotics that interfere with a full life,

And two main players—politics and money—will most likely always play central characters in our future drama for health and happiness. In the United States we are not even able to come to grips with the moral imperative to establish a single-payer system. Given the huge discrepancies in healthcare access, much of what I and other practitioners deal with on a day-to-day basis is so incredibly wasteful, including days filled with burdensome prior authorizations, prescription eligibilities, and delayed and denied treatments. Insurance companies may be practicing legalized gambling or perhaps legalized stealing, but we clearly should prefer high quality health care instead of insurance company and bank buildings being the highest peaks in the vista of urban America.

Many of us practitioners chose medicine to provide at least some intellectual stimulation, but the realm of day-to-day medicine is inundated with such a peculiarly high percentage of insurance and governmental interference that it drains our energy and spirit. Perhaps a single-payer system will not be a problem in the afterlife, but if this world is any reflection, the challenge may be a comprehensive single prayer system.

Invention, of course, can be used for evil, scare tactics, and to make you feel inadequate in your life, and perhaps more miserable than you already feel on most days. Here's what happens when you turn on the TV. Here comes the announcer. "You work hard all your life and then you are diagnosed with mesothelioma." Or, "One in 6 men get prostate cancer." Either you are inundated with depressing statistics or you reel from the way the pharmaceutical companies appear to invent disease so that they can be financially reward for treating them, medicalizing every symptom that a human may have and making sure you feel uncertain and in need of help. And access to comprehensive care can be quite problematic for many, despite the political sword-clanging and verbal bravado that offers improved changes in coverage.

Jared Diamond wrote, "Modern medicine has become synonymous with complex infrastructures and towering superstructures: with universities and professional organizations, multi-national pharmaceutical companies and insurance combines, hospitals doubling as medical schools, research sites and lobbies, government departments, international agencies and corporate finance." He continues, "Medicine in mass society inexorably became inseparable from economics, central and local administration, the law, the social service and the media."

As we continue in this book, we highlight the history of disease and our inventive interactions, reflect on the present, and attempt to outline a possible scenario of the future. What we are suggesting is something new, inventive, and hopefully quite helpful in molding our future.

Chapter 2

Germs, Genes and Geography

> The art of medicine consists in amusing the patient while nature cures the disease. ~ Voltaire

When we speak of disease, perceptions vary depending on where you are from. In modern Western medicine, disease is a biological or biochemical entity that can be targeted with evidence-based medications. Traditional Chinese or Indian healers, and indeed even Hippocrates viewed diseases as an imbalance between the human body and nature.

Robert Koch, in 1876, discovered the bacterium that caused anthrax and this led to people viewing disease as being caused a specific entity caused by a specific etiology. Such 'Germ Cell' theories then led to the development of antibiotics, which led to the ability to treat most bacterial infections. 'Coughs and colds' are mostly viral, even if they can cause secondary bacterial infections. In making antibiotics available widely to the general population, these drugs have become overused and commonplace, and bacteria have fought back – their natural selection processes creating super-strains resistant to antibiotics. This has now led to many bacterial super infections that are resistant to commonly used antibiotics.

Three factors that affect illness can be summed up as the 3G's – Germs, Genes and Geography. We've discussed bacteria and viral illnesses like influenza – human genes play a part in determining how an individual or a population responds to an infection; likewise bacterial genes play a part in how the bacterium evades the human immune response system. Geography also plays a part. Most vector or insect borne diseases are prevalent in the tropics, as in colder climates most insects are forced into hibernation during cold periods. Although with air travel and increasing migration

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of people many diseases confined to the tropics are now also found in other areas of the globe.

Benjamin Franklin once said, “All diseases may by sure means be prevented or cured, not excepting that of old age, and our lives lengthened at pleasure even beyond the antediluvian standard.” The medical utopian aim is to eliminate disease. Dr. Alfred Gilman, a 1996 Nobel Laureate, described the new era of medicine by saying, “in perhaps 50 years every molecule in the human body will be known. You'll be able to design a drug that works only on the molecule you want and on no other molecule in the body.” As molecular medicine gets closer to this aim it is important to look back at the role diseases have played in shaping our evolutionary destiny.

The original Hippocratic Oath began with the invocation, “I swear by Apollo the Physician and by Asclepius and by Hygeia and Panacea and by all the gods …” One of the symbols of the Asclepian cult was the serpent and the staff – which is now widely used as a symbol to represent modern medicine. This actually became a popular medical symbol only after its adoption by the U.S. Army Medical Corps at the beginning of the twentieth century. Some doctors are of the view that this represents *Dracunculus medinensis*, the Guinea worm. The worm emerges from the human host via painful ulcers it causes on the feet. These blisters burn and the patient may immerse the affected area in water to cool and soothe it. The worm senses the temperature change and discharges its larvae into the water. The traditional treatment was to slowly pull the worm out of the wound over a period of hours to weeks by winding it around a stick. If you were too rough and the worm broke off, it would cause a serious allergic reaction and even death. About 20 years ago, 10,000 new cases of Guinea worm infestation occurred per day in Africa. Fortunately eradication efforts have led to a massive reduction and today, in Africa, a Guinea worm infestation is reported every 10 days. This disease is going to end up the second disease to go be eradicated, after smallpox.

Speaking of smallpox, undoubtedly the greatest success in disease eradication has been the triumph over smallpox. One of the misconceptions about the term eradication is that people often equate this to elimination. Eradication is the worldwide reduction of the number of new cases of a disease to zero. But smallpox was unique as it was easily recognized due to the rash it caused; further it was transmitted only by humans – this allowed for “ring vaccination” i.e. vaccinating anyone exposed to a smallpox patient.

People hope that malaria can be added to this list of eradicated diseases as it kills over a million people a year. Organizations like the Gates Foundation are leading the battle against malaria. Later in this book, we will discuss the battle to eradicate malaria in more detail. However, with an estimated annual cost of 5 billion dollars to maintain the attack on malaria, there are concerns that political and corporate funding streams may not be able to sustain this effort. Further, the lack of an animal reservoir makes controlling a disease easier. Diseases like malaria that use animal vectors (mosquitoes) are a different proposition altogether.

It is obvious natural selection has played an important part in evolution and the shaping of animal (and for that matter, plant) populations. In 1918, the First World War came to an end. World War I is considered the deadliest conflict between nations, claiming 16 million lives between 1914 and 1918. Yet at the end of World War I, the influenza epidemic (commonly referred to as "The Spanish Flu") caused nearly twice the number of deaths. The human population of the Earth in 1918 was 1.8 billion and today the human population of the Earth has burgeoned to 7 billion! Even a major medical catastrophe seems to be a mere blip in unstoppable human population expansion.

Harvard University socio-biologist Edward O. Wilson estimates the "carrying capacity" of the Earth to be a maximum of 10 billion people. Wilson bases his estimate on calculations of the Earth's available resources and concludes: "If everyone agreed to become vegetarian, leaving little or nothing for livestock, the present 1.4 billion hectares of arable land (3.5 billion acres) would support about 10 billion people." Wilson states in his book, The Future of Life (Knopf, 2002), "The constraints of the biosphere are fixed."

John Burdon Sanderson Haldane was an Eton- and Oxford-educated Scotsman who went on to become one of the most influential thinkers in the field of genetics and evolutionary biology. A true polymath, with astounding scientific foresight (he even predicted test-tube babies in his writings in 1924), he was considered a bit of a rascal by the establishment (mostly for his enchantment with socialist ideology). Haldane ended up migrating to India, where he found kinship in Calcutta (now Kolkata).

Haldane made huge contributions to the fields of genetics, biochemistry and in the study of population fitness. Haldane hypothesized that species that produced millions of offspring, like marine species, would be mainly eaten by predators; in contrast, species that had less predatory deaths, like humans, would lose more numbers from disease. Otherwise species would increase without limit. If two species are in competition, then a disease may be an advantage or a disadvantage to either. Once a species dominates as humans do, lack of space or food sources create a density-dependent check. Haldane felt that diseases were therefore necessary to check population overgrowth.

Are disease and health like yin and yang? YinYang is the Eastern philosophy that says that all aspects of life have complementary forces. Yin denotes femininity, the earth, darkness and absorption; Yang denotes masculinity, heaven, the light and penetration. This line of thinking permeated Chinese medicine, government and art. In Japan, the equivalent principle, in-yō even had a government bureau dedicated to compliance with such principles as early as 675 AD.

As a writer and teacher of literary fiction, I am of the view that anything or anyone has the potential for change – it is the environment that matters, not our inherent genetic make-up. Dean Koontz, the thriller writer disagrees and once said that to write a thriller you had to believe evil was real and amongst us – that some people are born evil and simply incapable of reform. In one of J.K Rowling's Harry Potter books, Lord Voldemort says: "There is no good and evil. There is only power, and those too weak to seek it. Illness and wellness may similarly be necessary adversaries".

René Descartes in his book Principia Philosophiae (Principles of Philosophy) wrote: "Cogito ergo sum" (I think therefore I am) which became a fundamental Western philosophy – we exist to think, just as our thinking proves our existence. As an evolutionary biologist and a doctor, I have come to realize this equivalence about disease causing organisms: Vivo ego, ergo (I live, therefore it does). Disease has co-existed right through evolution and made us stronger. Understanding this not only helps us combat disease but overcome it by modifying our lifestyles.

Medicine is littered with organisms, symptoms and diseases marching together in a cavalcade, their arms linked, surging down the evolutionary path. Before them and after them, whichever animals wished to survive would have to make the same long trek of passage. Think sickle-cell disease and the protection it affords against malaria; think morning sickness only to realize that it coincides with the period of rapid tissue differentiation of the fetus – an unhealthy meal in the morning could lead to developmental defects; think anemia caused by iron that has accumulated in the liver (and therefore lacking in blood) and you'll realize that it is our body cleverly starving bacteria of this vital nutrient they crave as they invade us during chronic infections. This is natural selection at its ingenious best – developing bodily conditions to combat pathogens; likewise bacteria and viruses in turn develop a co-defense or die out.

When we think of evolved human reflexes, coughing or sneezing come to mind as they obviously expel unwanted substances. When is a sneeze not a simple sneeze? ACHOO – when we were medical students, it was a party trick to try and come up with rare or esoteric syndromes. It is easy to understand sneezing as a simple defense mechanism to expel foreign objects like dust in our nostrils. In 1985, when I was at medical school, Forrester described the ACHOO syndrome. ACHOO stands for Autosomal Dominant Compelling Helioopthalmic Outburst syndrome – which is characterized by uncontrollable sneezing in response to the sudden exposure to bright light, typically intense sunlight. It turns out that when we were cavemen and lived in the dark, this reflex helped us clear our airways when we were exposed to light on exiting our caves. Even today people that inherit this gene sneeze when they drive out of a tunnel, for instance. From the point of view of an invader, triggering a sneeze may have other benefits. We sneeze when we have a cold because it allows the virus to disseminate its particles widely. As we can see, the motto, 'adapt or die' is a truism for both organisms and disease.

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As my medical practice specializes in skin cancer medicine and reconstructive surgery after skin cancer, I am often referred patients with skin cancers on their ears. One of the risks of any trauma to the ear cartilage, even after surgery in sterile controlled conditions, is the risk of an infection – which we medically term perichondritis. One of the first signs of an infection in surgery is an increase in pain – I always tell my patients after a complex ear reconstruction: "Ring me if you have any increase in pain on your ear after the immediate post-operative period, unless you want to have ears like an All Black."

Rugby is religion, not sport in New Zealand where I am based – rather like cricket in India, or soccer in Brazil. If you look at the ears of All Black (New Zealand's national team) Rugby forwards, most have deformed "cauliflower ears" caused by injury that has led to perichondritis. Treating such infections aggressively – by draining infections when needed and using antibiotics, one can prevent "cauliflowering" of the ear. When I was attached to a plastic surgical unit, I once approached local rugby clubs to see if they'd like me to be an adviser to their club doctor in helping prevent these unsightly ears. They smiled and declined politely. When I investigated further I realized that most players did not achieve these ears on the battlefields of rugby – rather most had either punched themselves (or others) in the locker rooms to acquire these ears, which were worn as a badge of fearsome pride. A few years ago, I remember Chuck Palahniuk (who wrote The Fight Club) investigating Greco-Roman wrestlers in the US collegiate system – he had also noted that these trademark cauliflower ears were mostly acquired by banging their heads against lockers.

Ear cartilage infection (perichondritis technically refers to the infection of the connective tissue surrounding bare cartilage) is usually due to a bacterium called *Pseudomonas aeruginosa*. Pseudomonas is an organism that grows virtually anywhere – hence it can invade relatively bloodless fields like ear cartilage. It has even been known to grown in bottles of disinfectant in hospitals! No wonder then that if you observe colonies of Pseudomonas in a petri dish, you get a fast-forwarded lesson in evolution.

Dr. Joao Xavier of Memorial Sloan-Kettering Cancer Center and his colleagues studied a common species of *Pseudomonas aeruginosa*. They laced a petri dish with sugar and decided to see how these bacteria would forage for food. Strands of Pseudomonas created a gooey carpet and then used their tails to propel themselves along this slippery surface towards sustenance. The team grew about a hundred microbes initially, and allowed them to reproduce and swarm. Each day they removed some and added new colonies. The idea was that if a mutation developed during these replications, they could study the effects. But what they found was astounding. Within a few days, the evolution of these bacteria took a dramatic turn. The offspring moved much faster than their parents' generation — Dr. Xavier dubbed them 'hyperswarmers.' Unable to believe that nobody had filmed this before, the research team made a movie of hyperswarmers illustrating the process of natural selection. An ordinary *Pseudomonas aeruginosa* bacterium sports a single tail. These hyperswarmers had evolved so that they had as many as half a dozen tails. Those extra tails gave the bacteria more speed. And when the DNA of these super-bacteria was sequenced, they discovered all multi-tailed bacteria had a single gene mutation, called FleN. Somehow a mutation of this FleN gene causes these Pseudomonas organisms to develop more tails.

Bacteria are fundamental to the development of the immune system. When bacteria first invade organs such as skin, an innate immune response is triggered – these consist of white blood cells and macrophages that engulf bacteria or secrete biologically active chemicals. Another method is the use of complement – a cascade of plasma proteolytic (breakdown of proteins into smaller amino acids) reactions that occur on bacterial (but not host) surfaces and cause resultant inflammation. The hosts (such as humans) not only benefit from bacteria by their fine-tuning of our immune systems, but bacteria can also teach our cells to modulate their behavior.

One of the basic rules of biology goes like this: all organisms generate energy by absorbing nutrients from the environment. As nutrients are digested by enzymes, chemical bonds are formed and broken – leading to a release of energy. This energy then powers the cells. However, all this microscopic machination generates waste or garbage in the form of electrons, and therefore an 'electron dump' is essential. Sometimes, the garbage collector may take the form of oxygen, which is great at accepting electrons.

One of the questions that puzzled researchers was to do with these electron dumps: Oxygen is abundant in the atmosphere nowadays, but in primitive Earth it was very scarce. So what did bacteria use as electron scavengers? One explanation lay in minerals such as iron, which is an excellent electron absorber. However, most iron ore was on rocks, in molecules that were too large to enter a bacterial cell. What did bacteria do in ancient times? They simply developed molecules that shuttled electrons from inside the cell to iron outside their membranes.

Diane K. Newman, professor of biology and geo-biology at the Massachusetts Institute of Technology is one of the leaders in this field. While studying these electron dumps, she came across a class of molecules called phenazines. Phenazines have a very simple chemical structure: three carbon rings joined together, a couple of nitrogen atoms in the middle and oxygen here and there. But in their simplicity lies their brilliance as carriers of electron-waste – they simply swap electrons back and forth and this has allowed organisms to survive in times when oxygen was low in the environment.

Pseudomonas aeruginosa when seen under a microscope looks like a sausage with stringy appendages. These fine strands allow the bacterium to grip as it slides along moist surfaces. These Pseudomonas produce at least four different phenazines – designed to ferry electrons to both iron and oxygen. These help Pseudomonas to survive in conditions with and without oxygen. Sometimes when colonies of Pseudomonas produce a dense "biofilm", the deeply embedded layers lack oxygen and for these cells phenazines are lifesavers.

But phenazines are more than electron shuttles. At the surface of a *Pseudomonas aeruginosa* bacterial colony, they react with oxygen to produce molecules that are toxic to other bacteria but not Pseudomonas i.e. manufacture their own antibiotic. But even more important than their role as drug manufacturers is their function as oxygen-savants. These phenazines also tell the 'cell' how much oxygen is available outside by activating certain genes that not only inform the host but also educate the community. Far from acting as single cells, these single-celled creatures, when assembled in numbers, behave like other multicellular creatures and thereby discover the power of community spirit and social networks.

Speaking of Pseudomonas, researchers recently genetically engineered an *Escherichia coli* bacterium to carry pyocin that is deadly to Pseudomonas. This made the *Escherichia coli* bacterium work as a 'bacterial suicide bomber' by blowing itself up inside the Pseudomonas bacterium and releasing the deadly pyocin toxin. But will such interventions prove foolish? Will Pseudomonas end up developing deadlier strains immune to pyocins?

Bacteria may look something like microscopic meddlers that evolved over centuries through unplanned, unregulated processes that left them with things like beta-lactam rings that afford them antibiotic resistance. Ultimately, natural selection may be adequate for evolution, but that doesn't make it optimal. Bacteria and viruses understand this – they collaborate on a goal to create superior humans who if left to their own devices would simply die out.

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> A physician is obligated to consider more than a diseased organ, more than even the whole man — he must view the man in his world ~ Harvey Cushing (Attributed by Rene Dubos, Man Adapting (1965, 1980), Chap. 12, 342)

We have to ask the question Haldane asked – is disease necessary as a "killing agent"? Agriculture became prevalent relatively recently, a mere 10,000 years ago. This led to a massive increase in human populations. But agriculture also brought man in close proximity to domesticated animals and rodent pests. *Yersinia pestis*, a gram-negative anaerobic bacterium that affects rodents, afflicted humans and led to a deadly plague epidemic termed "Black Death" in the late 1340s, which killed an estimated 25 million people – a third of Europe's population at that time.

Until now, we have been speaking about bacterial infections. The Plague that decimated the population of Europe is a good example of why other diseases may have evolved to protect the human species. Macrophages in our body fluids normally carry off infectious agents to the lymph nodes to be destroyed. This is why diseases like tuberculosis and bubonic plague cause swollen lymph glands. In a disease like the bubonic plague, these bacteria use iron present in macrophages to multiply and develop. If a person was to be afflicted by hemochromatosis, a disease characterized by iron overload in the body we might surmise that they would be more vulnerable to bacteria like Yersinia. However, in hemochromatosis the macrophages are deficient in iron, as the iron is stored in excess in organs like the liver and spleen. This makes those afflicted with the hemochromatosis gene more resistant to the bubonic plague. When a third of Europe was killed off by the plague, hemochromatosis became more prevalent to preserve the human population. In Survival of the Sickest: a medical maverick discovers why we need disease (Harper Collins, 2007), Dr. Sharon Moalem elegantly researches the medical history of his grandfather who had Alzheimer's disease to discover he had hemochromatosis – and describes the origins of this disease.

From the age of agriculture 10,000 years ago until today we can sum up threats to survival as accidents, famine, predators and infectious diseases; a similar list now would read atherosclerosis, diabetes, cancer and infectious diseases. In 1900, the three leading causes of death in America were pneumonia, tuberculosis and dysentery (all infectious causes); in 1990, the three leading causes of death in America were heart disease, cancer and stroke (all lifestyle causes).

Atherosclerosis and diabetes cause more deaths in the Western world than any other cause. As modern man migrated out of Africa around 100,000 years ago, salt and sugar was scarce in the diet. When individuals ate fat, this was rare and this gave them an advantage as they could survive famines better. Now we have created worlds where sugar and salt abound in "fast food" and we consume large quantities of fat – all of which lead to early death.

Infectious diseases caused by bacteria and viruses have endured through time. Why has the process of natural selection not protected the human race from these pathogens? Simply because not only are these creatures also evolving, but small bacteria like *Escherichia coli* reproduce every 20 minutes and therefore their population grows exponentially. They have much more opportunity for mutations and natural selection than we do in centuries.

Let's say humans had the best hearing or sense of smell of all creatures – all the noise or aromas would probably be distracting; if we had unbreakable limbs that were not hollow, it would make us lumbering clumsy creatures. I was recently asked to speak at THiNK, a major ideas conference alongside Moran Cerf, a neuroscientist from NYU and Dr. Alan Russell, a pioneer of regenerative medicine. Dr. Russell spoke of growing human tracheas in the lab, testing new heart pumps and re-growing limbs like a newt does. While medically and scientifically exciting, this raises bio-ethical questions – where will this journey take us and what does it mean to be human? Does what is good for the newt become good for a human?

In linguistics, "portmanteau" is a term used to denote the combination of two words to make up a third; common examples are smog (smoke and fog) or motel (motor inn and hotel). In 1956, Herbert A. Simon came up with a portmanteau combining "satisfy" and "suffice": satisfice. Simon felt that human minds are reliant on memory and therefore unreliable. It is difficult for us to know the results of our actions in the future with precision. Therefore we rationalize things, i.e. we say, "… given the time and money available, this is the best decision we can make." Spoken like a true economist? Herbert A. Simon was one. But if we could foretell the outcome of our actions, we'd be satisfied that our decisions were optimal and sufficient; we'd rest satisficed. But in engineering body parts to create bionic humans, or regenerating tissue to regrow tissue lost due to accidents or disease, we don't know the outcome. Evolution and nature seem to have an innate knowledge of outcomes that are beyond what we can fathom. The problem with human minds is as Napoleon Bonaparte once said: Forethought we may have, undoubtedly, but not foresight. Nature always knows better.

Given that the population has already reached three-quarters of Earth's capacity, as populations age and diseases related to atherosclerosis are more and more aggressively treated – there is a real risk that the world will become over-populated. Around 1800 Thomas Malthus felt that a stable population could be maintained only through wars, famine, and plague, or voluntary 'moral restraint.' As the population grows to bursting point, unchecked by disease, future wars will be fought over basic human needs like food and water.

Without bacterial infections, would the human body continue to evolve as it has done? When humans began to consume milk and dairy a mere 10,000 years ago, the body had to evolve to develop lactase, which helped breakdown lactose, the sugar present in milk. When people tested bones dated to between 5800 and 5200 B.C. for a genetic marker associated with the production of lactase – they found no trace of the lactase gene.

We know that species evolve rapidly when they go through "evolutionary bottlenecks" – diseases that wipe out majority of a species or major changes in diet – those that survive end up resistant to the disease and create stronger populations. The same is true of failed efforts to eradicate a disease. If a disease eradication strategy fails after "nearly" eradicating the disease, it is likely that the disease will emerge stronger, affect more species and end up making a comeback. Sara Gorman, of Harvard University, in writing a PLoS medical community blog worries that the pursuit of disease eradication may be detrimental. Firstly, a claim of eradication ends prophylactic efforts and trained health workers; if lifelong immunity against the disease is not possible, a resurgence of the disease would be disastrous. And, as we have seen diseases, both infectious and metabolic help hone the immune system or protect against pathogens. Is disease eradication really visionary or a tilt against windmills? Does the huge cost of eradicating a disease like malaria outweigh the public health burden caused by the disease? Or will the disease simply move to other creatures and return with a vengeance? The risks of eradicating disease aside, one must also look at the economic costs. The current healthcare crisis is partly due to increasingly expensive genetic and molecular treatments that can treat diseases previously considered incurable.

In conclusion, let me quote George Santayana, the Spanish-American philosopher and essayist, who once said, "The diseases which destroy a man are no less natural than the instincts which preserve him."

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Chapter 3

Is Aging a Disease?

You can't help getting older, but you don't have to get old. George Burns

Old is new. This means that while there have always been some people who have lived well into their seventies or eighties or even beyond, the magnitude of this longevity today is a very recent development among the human species [1, 2].

The facts of global aging are quite amazing. A record-breaking rate of 800,000 new members enter the 65+ cohort per month. The geographic distribution of this growth is surprisingly uneven. More than three-quarters of this burgeoning global growth is in still-developing countries [3–6].

Most of this information on population and aging predictions is based on data that has been accumulated and is now being projected like an enormous flashlight into the future. But what about the role of our future technology and how that will change the map? How many people predicted our seismic shift in communication and data accumulation 50 years ago? What about life extension by new inventions and technology?

No internationally accepted standard to define someone as being "elderly" exists, nor has there ever really been any attempt to define characteristics that, once accumulated to a certain degree, officially shift a person's classification in their society from "adult" to "elder" [7]. The term "elderly" is an arbitrary term that, on a superficial basis, differs from culture to culture and region to region [8]. Most people in developed countries would classify someone as being elderly when they approach the age they are capable of receiving pension benefits or reaching tax exempt status; a

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generally agreeable age would be 65. While the UN has no official cutoff numerical criterion, it is known that they generally agree on the age of sixty as the point where any culture would agree that adult and elder reach an equilibrium [9, 10]. The difficulty in marking someone as elderly based on chronology comes as no surprise, seeing as how making a calendar age as the threshold of what is or isn't elderly would have to match up to a biological age, which definitely is not at all the same from person to person or culture to culture [11]. So then there comes a point, in medicine's attempt to define who is and isn't elderly and to try and make tangible the process of aging, the need to define a parameter that can be used universally and apply a definition does not change, something that in itself can convey more information than simply a number, although its application would have to still be relative to the reference group.

Life span suggests the average limit to which a member of a species will survive. Life expectancy is the proportion of that life span that a given member of the species will achieve. At some point, when a person's chronological and biological or functional age, or some blend of the two, reaches a certain percentage of life expectancy, one can be deemed elderly for the most part, from medicine's perspective [12]. These quantities are constrained by their upper limit which is set by the process of aging. Aging is defined as a time sequential deterioration of living things that is prompted by increased susceptibility to disease and adverse events, leading to loss of viability and physiologic functions. It is the degree to which physiologic functioning and adaptive responses are lost that paints a still somewhat unclear picture of what biologic age a person has attained. Aging is the process by which a living organism's disease state increases to the point that slightly less and less adverse situations are able to take a larger toll on it until it can no longer function [13–16].

The most vital component a person has for surviving the harsh conditions and avoiding the friability of aging is their body's immune system. Aside from simply thinking of being necessary to clear antigens from the body, the immune system is equally important in keeping the body's own physiology in check by monitoring for reactions that may go awry and unchecked, leading to malignancies, or helping the body rebuild and reshape itself in the face of any stress. Decreased ability to cope with stressors would support the notion that aging, which by definition eventually brings about the onset of becoming "elderly", and is marked by an increase in disease states and inability to withstand stresses that would be expected to be handled by the immune system, is itself a disease state. That lack of strength in the face of physiologic adversity implies that this disease state is brought about by an ever decreasing efficiency of the human immune system [16, 17].

Although it cannot be argued that people do become more prone to disease with age, but there is varying validity to whether aging represents an actual state of immunodeficiency. While aging is not accompanied by a profound drop in one of the many variables used to assess immune status with respect to a specific disease-i.e.-a viral load, T cell count, gamma globulin, etc., does the gradual decline in the immune function eventually constitute an older person as immunodeficient? Without the benefit of specific laboratory derived values to measure in discrete steps a shrinking of immune function, the concept of immunodeficiency being a disease state of the elderly might itself be arbitrary [16, 17].

Analysis of the aging body, albeit from a strictly physical standpoint without regard to being organic and arguably more complex, does point to some validity in the concept of a truly finite drop in immunity with age that can't be refuted. If you pour a glass of water out and allow it to form a puddle on a surface in your house, and just leave it alone for a day or two, when you come back to it would you expect it to still be there? The answer is no. At the same time, if you ask anyone with even a moderate degree of secondary education at what temperature water boils, they know it's 100 degrees (in Celsius at atmospheric pressure). So, if it's not 100 degrees Celsius in your house, and you aren't living at the top of Mount Everest, why did the water still dry up? The reason is that all systems will move into a state of maximum disorder if given the opportunity and not driven to do otherwise by outside forces. The water molecules in the puddle, being tightly bound to four others by hydrogen bonds in a neatly arranged network are much more ordered but energetically unfavorable compared to molecules in the vapor phase that move purposelessly through the air in the room freed from the restraints of their hydrogen bonds. This state of disorder minimizes the free energy of the system, and the energy lost in the process is known as entropy [16, 17].

When it breaks down, even the extremely complex and massive molecular structures that comprise a human cell are governed by the same laws of thermodynamics as the array of water molecules. Therefore, to allow genetically pre-programmed cell death, telomere depletion, or some other macromolecular structure or process to account entirely for the aging process alone would be insufficient. Under scrutiny, are the mechanisms that drive life simply large puddles of chemical potential that are ultimately subject to the same fate of thermodynamic instability as every other atomic particle? On a gross scale, manifestation of this instability would appear as a failure of the person to compete with stresses and maintain homeostasis –the overall purpose of a properly functioning immunity--and ultimately failure of every other organ system. This concept of ever increasing entropy comprises the most basic component on what is known as the damage theory of aging [18, 19].

While the damage theory of aging can propose that the root of decline in function and homeostasis is due to entropy on a global scale, this can be applied to the perspective of failing immunity specifically. It is strongly believed that as we age, over the course of decades of our bodies enduring pathology, be it trying to keep a latent infection of toxoplasmosis or herpes zoster under control, to every other stress and strain that requires some component of the immune system's action to guide us back into homeostasis, a degree of chronic inflammation begins. This chronic inflammation continues to grow and smolder in the internal environment until there comes a point where it continues even in the absence of an ongoing acute reaction to fuel it [19, 20].

Immunity's actions to prevent damage in the acute phase come with a long-term price. A major product of these excessive inflammatory responses includes the overproduction of reactive oxygen and nitrogen species that initiate redox reactions within the cellular environment. Left unchecked these are thought to lead to a depletion of the cell's scavenging enzymes that are needed to inactivate the radicals when the oxidative stress is no longer necessary [19, 20].

The inappropriately abundant radicals that result from an overworked and now slipshod inflammatory response directly facilitate the thermodynamic breakdown of the cells' molecular constituents, and extend to them their state of disorder. Their exothermic reactivity results in, for example, proteins losing their intricately arranged and structurally functional three dimensional shapes and resorting to a more disordered yet energetically favorable string of purposeless amino acids. It is interesting that these same oxidative/reduction processes, when delicately orchestrated so that their free energy loss may be contained and coupled to a useful process as opposed to just dissipating as heat and promoting entropy, provides the electromotive force that indirectly drives all of life's vital workings by regenerating ATP via the mitochondrial transport chain. This is the major downside to chronic inflammation. These oxide and nitrogen radicals are, however, absolutely necessary in the short term. They are one of the vital players in the immune system's destruction of foreign pathogens during the acute inflammatory response [18–20].

The acute inflammatory process forms the basis of host defenses, tissue repair mechanisms, and a return to homeostasis when faced with stress. The heart of the problem, although seemingly paradoxical, behind the development of chronic inflammation leading to an unregulated immune system is that humans are living so much longer thanks to medical science. Human beings were meant to utilize the acute inflammatory response as a means of protection against their external environments so they may fulfill the same goal that mother nature intended for them, as is the case for every other living organism-to survive to reproductive age so that they may assist in the propagation of their species. This is the sole factor that determines an individual organism's "success" from an evolutionary standpoint.

We as a species have outpaced evolution's method of natural selection as the way to extend lifespan via advancements in medical treatment. As people are able to live longer, we are exhausting our immune responses far past what evolution has intended. The resulting excessive exposure to external and internal stresses and repeated cycling of activation and then (albeit progressively less and less successfully) deactivation of the acute immune response with continuous macrophage migration into tissues is what eventually tips the scale in favor of chronic inflammation. The damage due to the inflammatory response starts to outweigh the benefit of the acute response. This concept, called "inflammaging", is the result of the immunosenescence that inevitably must accompany the ever increasing aging process/duration. Inflammation is the driving force behind the decrease in immune capacity, or relative immunodeficiency that allots the increase in likelihood and severity of disease process in the elderly [18–20].

In conjunction with using entropy and oxidative damage as a buttress for supporting the "inflammaging" process, there exists tangible evidence for a chronic inflammatory state that worsens with chronologic age. This evidence properly correlates with the notion that an overly activated but improperly regulated inflammatory process accompanies aging and overall decreases the efficiency of the immune system. This is made evident by an imbalance in the levels of inflammatory mediators that have been illustrated in laboratory research. Other in vitro and in vivo studies have provided plausible mechanisms to account for the manifestation of immunodeficiency with macromolecular and cellular dysfunctions. Given the fact that we are now living in a time of a worldwide "silver tsunami", when the aging population is growing at the fastest rate ever, perhaps we need to register a worldwide "silver alert" that reflects how our runaway immune systems must be primed to care for the current abundance of aging and stress [18–20].

What's next?

Most of this information on population and aging predictions is based on data that has been accumulated and is now being projected like an enormous flashlight into the future. But what about the role of our future technology and how that will change the map? How many people predicted our seismic shift in communication and data accumulation 50 years ago? What about life extension by new inventions and technology?

Current gene therapies include somatic gene therapy, blocking or modifying gene expression, and influencing the metabolic expression of genes [18–20]. When we are considering overcoming the progression of disease or aging, how do we look at what is ahead? It is often advertised that we can "reverse aging". Really? In overcoming a disease we often use militaristic metaphors; the dangerous infiltration and progression of a disease that we are fighting is a war and it's important to mobilize everything in terms of weaponry that can be harnessed and all these enemies to our body should be attacked on multiple fronts. But is the same true of aging? Should we look at it as a disease to be treated with the same vengeance?

Aging in modern society has engendered as many conflicting opinions on issues and controversies as the number of researchers in gerontology. Historically, our bodies evolved and grew to an age of survival perhaps just past the child rearing years and was then not particularly useful. But now we live far beyond the earlier times in our existence and from an evolutionary view if we live into old age we are competing for limited food and other resources. And those resources will continue to be more limited—in Stephen Emmot's book *Ten Billion* he writes, "There are currently 3 billion people worldwide urgently needing to consume more: more water, more food, more energy. And by the end of the century they'll be as many as 5 billion who will need to consume more" [21].

Is trying to overcome disease and aging and extending human potential and human life what do the majority of us want to do? Perhaps this is not even important until we correct the enormous health discrepancies that currently exist. With a billions hungry and not getting adequate medical care on this planet, is it hubris to look for genetic therapies that may cost billions of dollars more and only be offered to the highest bidders?

In many ways we search with a global perspective for solutions that most health practitioners experience with individual patients every day—repairing the world after it has been messed up by past behavior. The patient with 40 years of smoking and eating too much fat and not exercising wants a magic wand waved over him to repair and prosper. Is that what society seeks with technological intervention? We won't have to behave. Everything will be fixed. We can just change the battery, stop the leak, change our genes, and keep on going.

Ray Kurzweil and Terry Grossman, in their book *Fantastic Voyage, The Science Behind Radical Life Extension* write, "Although we do not yet have all the tools we need to stop and reverse all aging processes, we do have the means right now to stay in good health and spirits until the full blossoming of the biotechnology nanotechnology artificial intelligence revolutions, which will indeed provide radical life extension". The authors write, "The essence of the human species is to expand our boundaries" [22].

"If we want to remain vital for as long as possible, we cannot simply rely on the natural order the biologic evolution has given us." These two co-authors are disparaging over those that state that the extension of human longevity is immoral and that adversarial opposition and regressive ideas to these processes only provoke delays in research and crucial therapies for a wide range of diseases and aging itself. Kurzweil and Grossman state, "Ultimately such opposition will end up being mere stones in a torrent of innovation, with a continued flow of progress passing around these barriers. But even minor delays will result in suffering death of millions of people" [22].

Each person has about one million genetic variants. As we gain more ability to revitalize our health and expand our longevity through genetic manipulation, we will be face with more decisions about our destiny as to what makes us human as we work to save our planet from the forces of destruction that Emmot and others expound upon. Yet perhaps we must be cautious about what we seek to add; as the saying goes, "The camel came to receive horns and they cut off its ears" [21].

With new changes we will add on and expand our experiences using full immersion virtual reality incorporating all our senses for augmented reality. Hopefully we will enhance human intelligence and longevity and disease prevention capability using nanotechnology to extend our bodies and brains. Kurzweil and Grossman state, "We will develop means to vastly expand our physical and mental capabilities by directly interfacing our biologic systems with human created technology" [22].

In the *Oxford Handbook of the History of Medicine*, Christopher Hamlin writes, "there are no a priori boundaries to the changes that might be promulgated in pursuit of health; hence public health and its history are inextricably entangled with political philosophy and practice. Even when historians are addressing themselves to colleagues, usually there's a secondary audience and an ulterior set of contemporary and eternal issues" [23].

To improve our health, we must rely on history, as Hamlin points out. "The evaluation of health status is itself in a historical problem: the effects of pathological or prophylactic influences on populations can only be measured over spans of time". He writes, "Public health is an important, if under-recognized, element of the great moral dramas of history – the struggles of peoples for better lives". And what of happiness and the quality of life? How do our future advances take these into account? Hamlin states, "It is difficult to talk about healthy population without implicating general issues of happiness, prosperity, and self-determination" [23].

So what should we choose? Read on.

We live in a time with a "silver tsunami" of aging. Investigating the concept of how and when we age, immunity, and dermatological manifestations in our elderly is a complex and challenging task.

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Chapter 4

Vaccines and Prevention

> Beadle believed that genetics were inseparable from chemistry—more precisely, biochemistry. They were, he said, "two doors leading to the same room." ~ Warren Beaver[1]

I was in my first week as a newly graduated doctor when I encountered a vaccine-skeptic – a patient who was convinced vaccines were dangerous and could weaken the human race. I remember thinking – as a doctor, I am supposed to take a detailed history, but I hope you forgive me if I switch off just for a little bit, because right now isn't the time for this debate. You learn something at medical school and immediately try to tell people about it, but you can't convince them – not easily anyway. Especially if you have been indoctrinated with factual information along the lines of this[2]: an estimated 1.5 million children die each year—one every 20 seconds—from vaccine-preventable diseases such as diarrhea and pneumonia.

When I was thirteen, I had my first experience of outcomes that such beliefs can lead to – one of my best friends, a would-be star track-athlete developed polio – when we were all lined up at school and given these bitter tasting drops (with a spoonful of sugar), Samuel had missed out as his parents had refused vaccinations for him. When you are thirteen, you

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[1] Warren Weaver, 'Science and Imagination' (1967), xii. Quoted in Thomas Hager, 'Force of Nature: The Life of Linus Pauling' (1995), page 276.

[2] Gates Foundation. 'The Challenge' http://www.gatesfoundation.org/What-We-Do/Global-Development/Vaccine-Delivery accessed Dec 25, 2015.

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couldn't care less one way or the other – parents tell you what to do and you listen – most of the time, anyway. Then you get older and start making your own decisions.

But unbelief in the concept or power of vaccinations had its own dangers. Samuel always seemed to be faster and stronger than us, until polio took effect – then he could barely walk. Maybe this was something his parents were not expecting. They finally had proof, but they perhaps couldn't tell it to anyone, because of the people they were – there was a need to make spiritual sense of their son's disability – and resolve a conflict with their religious faith, that had led them to believe that God wouldn't have given Samuel the talent at sport if he wasn't going to use it.

Even where I live, in New Zealand, a few people I know are strongly against all forms of vaccinations. And, they are all not Internet wackos. In fact shoddiness at some historical points of vaccine research is partly to blame. Samuel's parents refused to allow his being vaccinated, as they were staunch Jehovah's witnesses. But the history of vaccination has had a few manufacturing missteps.

I remember my father telling me about polio and its dangers. 1952 was the year he entered medical school. In that year, the American polio epidemic was the worst outbreak in the nation's history, he said. Of nearly 58,000 cases reported that year, over 3000 people died, and over 20,000 were left with mild to disabling paralysis. A few years earlier, Jonas Salk, an American doctor and virologist had accepted an appointment to the University of Pittsburgh School of Medicine. Salk felt that medicine owed a moral commitment to society to provide immunization from communicable diseases. He ended up making the world's first polio vaccine.

In an interview with the *New York Times*, Salk merely viewed himself as a 'highly evolved mutant' – one that could tap into the prevailing current of evolution and speed it along. He felt this was his guiding force:

> There is a dynamism, a dynamic force that propels us into the future, … I have come to recognize evolution not only as an active process that I am experiencing all the time but as something I can guide by the choices I make, by the experiments I design," he said. "I have always sensed this as the next evolutionary step. It's not something of which a great many are capable, but some are… That is the source of my guidance[3]

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[3] George Johnson, Once Again, A MAN WITH A MISSION. 25, Nov, 1990. New York Times magazine. http://www.nytimes.com/1990/11/25/magazine/once-again-a-man-with-a-mission.html?pagewanted=all accessed Dec 25, 2015.

On April 12, 1955, Jonas Salk's polio vaccine —made by inactivating poliovirus with formaldehyde— was declared to be safe and effective. The three-pronged trial of Salk's vaccine had included 1.8 million children who were inoculated with either vaccine (made by either Eli Lilly or Parke-Davis) or placebo or were not inoculated (but only observed). Given the scale of the epidemic, the Laboratory of Biologics Control rapidly granted licenses to produce the vaccine to five pharmaceutical companies: Eli Lilly, Parke-Davis, Wyeth, Pitman-Moore, and Cutter.

The granting of the licenses took only 2 hours; however, 2 weeks later, the Director of the Laboratory of Biologics Control, William Workman, was informed that five children in California, all first- and second-graders, had become paralyzed after receiving polio vaccine. In each instance, Cutter Labs had manufactured the vaccine.

Paul Offit, who has chronicled this sad saga, views the Cutter Incident as a turning point in vaccine manufacturing. On one hand, we had a terrified nation, desperately seeking someone to kill a dangerous beast lurking within its midst. Then Big Pharma arrived, boots, white-coats and all, to reduce the critter to a clump of smoking red coals. Once the flames receded, people were crying, not able to understand how these medical industrial misadventures work – to keep the spirit of pharmaceutical progress alive, a few lives are often sacrificed.

The Cutter Incident led to a landmark court case in California, *Gottsdanker v. Cutter Laboratories*, that I remember studying when I studied Medical Law at the University of Glasgow. Because the Salk vaccine was rushed through, none of the laboratories manufacturing the vaccine had experience in mass production of such a vaccine – and all had difficulty completely inactivating the poliovirus. Therefore, while Cutter was technically not negligent, damages were nevertheless awarded for 'implied warranty.'

However the Cutter case led to pharmaceutical companies' reluctance to embark on ambitious vaccine projects – in 2004 only four big companies were producing vaccines globally, and two of them had severely reduced their vaccine research programs. Vaccine shortages are increasingly becoming common – the most recent and most widely known is the influenza vaccine shortage that created a public health crisis. Truth be told, shortages are not unknown for vaccines against tetanus, pneumococcal pneumonia, and other childhood diseases.

In actual fact, the vaccine for polio we had at school (that Samuel missed out on) was the oral Sabin vaccine, developed after the Salk vaccine, which was an injectable version.

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Francis Darwin once wrote[4]:

> But in science the credit goes to the man who convinces the world, not to the man to whom the idea first occurs. Not the man who finds a grain of new and precious quality but to him who sows it, reaps it, grinds it and feeds the world on it.

So it was with smallpox vaccination. Edward Jenner is widely credited with discovering a vaccine for smallpox, even though the disease itself was known from ancient times – the mummified head of the Egyptian pharaoh Ramses V (died 1156 BC) bears evidence of smallpox.[5] In fact, the word smallpox derives from the term small pockes (pocke meaning sac), and was first used in England at the end of the fifteenth century to distinguish the disease from syphilis, which was then known as the great pockes.[6] In fact, smallpox had been reported in ancient Asian cultures – smallpox was described as early as 1122 BC in China and is mentioned in ancient Sanskrit texts of India. Even the practice of vaccination was actually introduced from Asia to Europe in the eighteenth century.

Before the formal process of vaccination was adopted, inoculation was the method to combat such infectious diseases – the inoculator usually used a lancet or needle and obtained pus or material from a ripe pustule of someone suffering from smallpox. This material was then introduced on the arms or legs of the non-immune person, thereby triggering an immune response. This was where Jenner made massive advances – with experiments using cowpox 'pus' on those infected with smallpox. In those days, in the eighteenth century, it was common knowledge amongst farm folk that those afflicted by cowpox never ended up with smallpox. It was reported that Jenner overheard a dairymaid say[7]: "I shall never have smallpox for I have had cowpox. I shall never have an ugly pock-marked face." This lead to Jenner formally testing his theory – Jenner showed that cowpox not only protected against smallpox but also could be transmitted from one person to another as a deliberate mechanism of protection. In spite of being acknowledged worldwide for his work in the field of public vaccination, Jenner remained a humble, interesting and altruistic character. He built a one-room hut in his garden, which he called the 'Temple of Vaccinia' – where he vaccinated the poor for free.

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[4] Francis Darwin. First Galton Lecture before the Eugenics Society', Eugenics Review, 1914, volume 6, page 9.

[5] AS Lyons, RJ Petrucelli II. Medicine—An Illustrated History. New York: Abradale Press, Harry N Abrams Inc, 1987.

[6] JC Moore. The History of the Smallpox. London: Longman, 1815.

[7] HJ Parish. 'Victory with Vaccines: The Story of Immunization.' Edinburgh: E & S Livingstone, 1968.

Smallpox eventually became the first disease for which mass vaccination was practiced, and appropriately it was the first disease to be eradicated globally in 1979.

At a basic level, vaccinations using 'live' agents induce immunity via one of the following methods – using a related virus from another animal, unnatural route, or unnatural cell type.

A related virus from another animal was the method used by Edward Jenner. The principles of 'Jennerian' vaccines was to make vaccines using infective agents that either do not cause disease or cause mild disease in humans, or for any animal being vaccinated. Jenner used cowpox against smallpox; in later years, using the same principle, BCG vaccine was made from *Mycobacterium bovis* – the agent that causes tuberculosis in cattle, to protect against human tuberculosis.

The principle of using an unnatural route hinges on the fact that viruses are known to be less potent if introduced via an unnatural bodily route – this was the technique used when military recruits in the 1970s were vaccinated against the adenovirus that causes Adult Respiratory Distress Syndrome (ARDS). This virus was potent and pathogenic in the respiratory system of humans, but when given via the gastrointestinal system (as enteric-coated tablets) they replicated without causing disease, thereby inducing immunity.

While Jenner showed that inoculating people with cowpox pus could prevent against smallpox, he did not understand or explain how the human immune system developed this protection. It was Louis Pasteur, the French microbiologist, who went a long way in explaining this. Unlike Jenner, Pasteur used inactivated vaccines. In the late 1800s, Pasteur experimented with the killed Rabies virus (that he derived from dried rabbit spinal cords) that he used to prevent disease in animals, and later humans. Remember Jonas Salk whom we discussed earlier? Salk essentially used the Pasteur technique – he grew poliovirus in a culture, then purified it and then inactivated it using formaldehyde – and then used it in an injectable form against polio.

The other method of creating live vaccines is to make the virus inactive by serial passage through unnatural or artificial cell types – for example one measles vaccine was made by passing it 24 times through human kidney lines, 28 times in human amniotic cells, 6 times in a chick embryo and 85 times in chicken fibroblasts. The idea in such cases is to create viral 'mutants' that are best suited to growing in such artificial media, but less dangerous when returned to the original host. Now that genomes have been sequenced and DNA technology is everywhere, it is possible to deliberately induce such mutations in human cells and this is where vaccine technology seems to be heading.

The problem with killed vaccines is that they don't last long; the problem with live vaccines is that they can be unstable and also interfere with each other; the problem with human beings is that they are fickle, and immune systems can be variably deficient or unpredictable.

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> We were not a hugging people. In terms of emotional comfort it was our belief that no amount of physical contact could match the healing powers of a well made cocktail. ~ David Sedaris[8]

It is difficult to imagine the history or sociology of Western society without alcohol – Scotch Whiskey, Irish Guinness, Rum from the Caribbean and American attempts at prohibition are all part of our collective consciousness. Louis Pasteur's name is irrevocably linked to both alcohol and vaccines. He was the first to conclude that fermentation is a vital (as in living) process, and he defined it as "respiration without air." The story goes that in the 1850s, a brewer named Bigo contacted Pasteur because he was having problems producing alcohol from beetroot fermentation. His containers were producing sour milk-like liquids instead of alcohol, and he sought help from Pasteur, as he was considered an expert in fermentation. When Pasteur examined the containers, he could detect large amounts of yeast from the vats containing alcohol, but in containers containing the abnormal samples there were cells much smaller than yeast. Pasteur concluded that there are two types of fermentation: caused by alcohol or lactic acid. Alcoholic fermentation occurs by the action of yeast; lactic acid fermentation by the action of bacteria.

Pasteur's findings had huge implications for the alcohol industry and Pasteur even patented his own beer-making equipment. Today alcohol is a huge industry. In America, where booze was once banned, Bourbon and Tennessee whiskey production resulted in $2.2 billion worth of revenue in 2012, according to a recent report from the Distilled Spirits Council of the United States. Most yeast strains can tolerate an alcohol concentration of 10–15 % before being killed. This is why the percentage of alcohol in wines is typically in this concentration range. For beverages with higher concentrations of alcohol the fermented products must be distilled, as is done with whiskey and other spirits (Scotch is whisky made in Scotland, while bourbon is whiskey made in the U.S.A, generally Kentucky; there is even a Bourbon law – 'Federal Standards of Identity' for Bourbon the law stipulates that for a whiskey to call itself bourbon, its mash, the mixture of grains from which the product is distilled, must contain at least 51 % corn, and there are specifications about how this must be distilled).

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[8] David Sedaris, 'Naked.' Hachette, UK, 2010.

However, like human beings, yeasts also have different tolerance levels for alcohol. Therefore, brewers and wine makers have to select different strains of yeast to produce different alcohol contents in their fermented beverages.

Yeast has uses in the vaccine industry other than the well-known uses in bread-making and brewing. If the previous generation of vaccines were using intermediate organisms or unnatural cell types to weaken the disease-causing pathogen, newer vaccine technology using recombinant DNA has found yeast as useful as brewers did. A small piece of DNA is taken from the virus or bacterium that we want to protect against. This is then inserted into the DNA of yeast cells. These yeast cells are then able to produce proteins from the virus, and this is purified and used as the active ingredient – this was method used to produce the vaccine against Human Papillomavirus that is implicated in certain types of genital warts and cervical cancer. Therefore, if the previous ideology behind vaccines was to prevent infectious diseases, we are now looking at 'vaccines' against cancers and non-communicable conditions. The paradigm has shifted from population health to more personalized medicine in the future where high-risk individuals may receive individualized vaccines. Of course, with such measures comes an invariable increase in cost and less democratization.

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Jones and Bartlett, writing about the AIDS Epidemic, loves to quote *TIME* magazine in 1981[9]: "(Genetic engineering) … the most powerful and awesome skill acquired by man since the splitting of the atom." But microbiology in particular has always been the forefront of evolution, as the Earth is littered with many different creatures. Unencumbered by size, viruses and bacteria, these little microscopic meddlers keep morphing into new forms and view us merely as companions and co-inhabitors, and not as superiors. Scientists by nature do not make people immediately suspicious that something is out of control, as they wait to study the evidence. The AIDS Epidemic is worth studying to see the response of modern science to ancient evolution. Everyone now generally agrees that SIV (Simian Immunodeficiency Virus) crossed over to man from monkey in the 1940s or 1950s, and this led to new strains of viruses that became HIV. It was evolution at its finest, these viruses had acquired a new fullness, a savagery – and what really mattered was if humans, in response would do the same, even with the advantage of scientific shortcuts.

In June 1981, 2 years before I was a freshman at medical school, the CDC wrote in its MMWR (Morbidity and Mortality Weekly Report) about five

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[9] The AIDS Epidemic. Jones & Bartlett Learning; 7 edition (February 22, 2013).

Californian gay men suffering from *Pneumocystis* pneumonia. These men had deficient T-cell immunity. In July 1981, there was another MMWR report describing Kaposi's sarcoma in gay men. These were relatively rare diseases surfacing due to immunodeficiency. Because the disease was only (at this stage) reported in gay men, doctors postulated possible causes based on known gay behavior (could amyl nitrate, a drug used by gay men cause this?) rather than recognizing this for what is was – a new transmissible virus. By early 1983, when I entered medical school, the disease had been reported in 16 countries, more than 1000 Americans were afflicted, and mother-to-child transmission and heterosexual infection had also been reported.

For the first three years of the AIDS Epidemic, the number of cases 'only' doubled every 6 months, almost as quickly as a new theory of its origins was hypothesized – all increasingly religious, conspiratorial, moral or microbiologic. It was in 1986 that the HIV virus finally got its name.

In the 1980s, Max Essex of the Harvard Public Health School recovered a virus in African Green Monkeys that was biochemically very similar to HIV. This virus was SIV. Essex's team theorized that perhaps the SIV had crossed over into humans via a monkey-bite. About a decade later, Vanessa Hirsh of the National Institute of Allergy and Infectious Diseases found a strain of SIV almost identical to that of HIV from Sooty Mangabey monkeys in West Africa. What both these researchers discovered was that like humans, viruses are extremely adept at evolutionary experimentation. More recently, in 2010, Preston Marx reported that SIV was prevalent in as many as 40 species of African monkeys for 32,000 years. Evolution is an ancient discipline; human memory and attention is short-lived – this reality is what makes the world perilous for us. In some ways as Laurie Garrett points out in 'The Coming Plague'[10] – we were fortunate with AIDS in that it gave us easy clues that a new organism had emerged: AIDS caused atypical infections (Pneumocystis) or cancers (Kaposi's) rather than the infections found in regular folk; it was first noted in gay men; it was first noted in the USA, a first world country with a highly developed disease control system, and further, scientists had just developed the ability to study retroviruses.

Yet, 30 years later, the Ebola Epidemic was allowed to get out of control for precisely the same reasons – but Ebola is different, vastly more aggressive – AIDS has a long latency period of nearly a decade while Ebola's latency is under a month – yet there was lack of funding as this was seen as an African virus. By mid-March 2015, the current Ebola outbreak in Guinea,

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[10] Laurie Garrett. The Coming Plague: Newly Emerging Diseases in a World Out of Balance. Penguin Books; Reprint edition (October 1, 1995).

Liberia, and Sierra Leone had reported over 24,000 cases, and close to 10,000 deaths including around 500 healthcare workers – causing Dr. Jim Yong Kim, President of the World Bank, to warn participants at the 2015 World Economic Forum[11]: "The world is dangerously unprepared for future deadly pandemics like the Ebola outbreak in West Africa."

The Médecins Sans Frontières (MSF) organization, whose doctors and nurses do selfless and amazing work in many troubled countries could not hide its frustration, calling the international response "slow, derisory and irresponsible"[12] adding, "Dead bodies in the street, families wiped out, dozens of health care workers infected, hospitals shut down and panic and mistrust in the eyes of the people in the streets." Hardly an encouraging picture, as this is unlikely to be the last epidemic the world or us humans shall face. The poor initial response to Ebola will have repercussions for all, not least of all the loss of medical experts in a continent where they are needed. As George Dvorsky noted in an article regarding the Ebola Epidemic[13]:

> The effects (of Ebola) will be felt for years to come. The loss of so many medical personnel is expected to have downstream effects on the health system of affected West African countries, including a sharp rise in maternal mortality to the tune of an additional 4,022 deaths each year for the foreseeable future. Moreover, the ability of healthcare workers to deal with other major diseases, like Malaria and Lassa (another hemorrhagic fever), was severely curtailed during the epidemic.

And, finally after plenty of handwringing and political maneuvering, an effective Ebola vaccine was made. The vesicular stomatitis virus (one that causes mouth ulcers and is relatively harmless) was genetically altered – a gene for its native envelope glycoprotein was replaced with that from an Ebola virus strain (Zaire, Kikwit 1995). This vaccine had been developed by the Public Health Agency of Canada and it had been patented as early as 2003, even though adequate human trials were not available until recently. Phase III (final stages of efficacy and safety) trials were undertaken in Guinea using 'ring vaccination' – an almost biblical process that involves identifying an infected person, their contacts, and their contacts' contacts and vaccinating them. The vaccine proved 100 % effective – and scientists hailed this as a potential game-changer. The early results, published in *The Lancet*, showed the vaccine had 100 % effectiveness when given immediately. However, there were 16 cases of Ebola in those that were (in the study) a part of the delayed vaccination group (0.5 %).

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[11] BBC News. 'Ebola crisis: World' dangerously unprepared' for future pandemics.' 28 January, 2015 http://www.bbc.com/news/world-31013636 accessed Dec 25, 2015.

[12] MSF. 'Ebola: the failures of the international outbreak response.' 29 August, 2014 http://www.msf.org/article/ebola-failures-international-outbreak-response accessed Dec 25, 2015.

[13] George Dvorsky. Approaching Zero: How West Africa is Crushing the Ebola Epidemic. Gizmodo, 26 October, 2015. http://gizmodo.com/approaching-zero-how-west-africa-is-crushing-the-ebola-1738267946 accessed Dec 25, 2015.

The panic when a new virus emerges out of Africa is surprising. After all, the same chemistry and DNA lies within the cellular frames of most creatures. The density or color of our blood, the patterns of our vertebral systems, the unreliability of our nerves may vary – but there is a certain commonality. When primitive humans left Africa about 100,000 years ago, our ancestral diets and behaviors did not matter, as they were but a speck on the surface of the Earth. Now we have, within a short space of time overpopulated, polluted and destroyed our environment to the degree that of all organisms to emerge out of Africa, *Homo sapiens* may indeed be the most dangerous of all. The Earth may be our hermitage – and nature's world may be wonderfully brilliant to behold – but nature is essentially non-discriminatory to color, friends, angels, parents, books or stories – ultimately, only the fingerprints of evolutionary processes matter. Therein lies the problem with industrializing immunity.

You see, there is fundamentally a problem with trying to create artificial immunity, as if we can gratify evolution or satisfy its needs. The problem with evolution and Natural Selection was that the process remained aloof from individual needs, solitary cries or quick satisfaction – all things that the vaccination industry seeks to now commercialize. Can intimacy between human and viral DNA end up being dangerous? This was the problem Penn State University Professor, Andrew Read pondered over. In 2001, Read proposed that "leaky" vaccines – ones that allow transmission of disease to organisms – might prompt the evolution of more dangerous strains of organisms. Read, an evolutionary biologist stumbled upon experimental evidence that vaccines can alter evolution – organisms we are trying to protect against ending up creating more virulent forms.

In 2001, Read published a paper in *Nature*, using mathematical modeling to predict that vaccination could alter evolution of viruses. But he lacked experimental evidence; until more recently. Read is cautious about the risks in the future from scientists engineering Ebola vaccines. Could vaccines make viruses evolve to more virulent forms? After all, it would be typically human and arrogantly presumptuous of us to assume we are the only ones evolving. We may be trying to create artificial men, but other creatures are happy enough to let their destiny be determined by nature's own devices.

Read began examining a virus that causes something called Marek's disease in chickens. In a series of experiments, Read looked at different strains of the Marek's virus. The older, milder strains kill about half of the unvaccinated birds in a couple of months, but the newer "hot" strains kill 100 % of infected chickens in 10 days – in other words all unvaccinated birds had no chance of survival. What caused this increase in virulence? Vaccines? To test this theory, he began looking at the population 'fitness' of these organisms – essentially evolutionary 'fitness' is determined by how good a virus is in replicating in different environments. What Read's experiments showed was this – the newer, more deadly or "hot" strains were 'not very fit' in unvaccinated birds – in other words if there were no vaccines against Marek's disease, these increasingly virulent forms would die away – the hot strains would burn themselves out by killing their hosts before they had transmitted the infection to other birds. But now, given the hot strain has been rendered fitter by the vaccine, vaccinated birds survive longer and thereby shed more virus – and thereby continue to transmit disease.

Read's ideas may be controversial, if only for the fact that his science is sometimes quoted by the anti-vaccine movement. But his experimental methods are sound and stack up scientifically. This year, his team's research and findings were published in the influential journal, *PLOS Biology*.[14]

Humans are increasingly full of manufactured parts, working valves and artificially enhanced intelligence, but at our core we are biological and biochemical beings. After all, as the American Society of Human Genetics noted, humans share over 90 % of their DNA with their primate cousins.[15] As we sleep, evolution is busy at work tinkering with little enzymes, proteins and genetic code; every time we wake, tiny invisible creatures have become wholer, fitter and more improved. And, as far as nature or our planet are concerned, there is no need to specifically guard or protect the human race – from their point of view such wasted energy is corny and has but the symbolism of a statue. And all statues shall eventually crumble.

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Chapter 5

The Future of Disease: Evolution and Ecology

> God has cared for these trees, saved them from drought, disease, avalanches, and a thousand tempests and floods. But he cannot save them from fools. John Muir

I will provide an evolutionary perspective as a springboard for further exploration of disease. The primary focus in human biology is genetic variations in the human species – micro-evolution – which result in diversity that reflects adaptation. Other factors include chance, the changes in alleles as a result of random factors such as genetic drift, and history, where different populations start off with different gene pools and experience different environmental conditions over time.

The examples that I will use to highlight micro-evolutionary processes will also hopefully help to illustrate contemporary health problems, including infectious and chronic disease. I will focus first on two of my favorite subjects, hair and skin, to help illustrate the crucial points.

Our hairlessness is the reason for the origin of melanin in sunny regions and its production just under the surface of the skin evolved in Africa, perhaps contemporaneous with our loss of hair. Our ancestors were dark skinned and when some moved from hot climates, the melanin that had helped protect the skin from the loss of folate and from sun damage resulted in blocking too much sun and producing vitamin D. Dark-skinned individuals were prone to rickets and perhaps subsequent death. Over time, the pale-skinned genes were favored during all northward migrations of humans. Light skin color exists because our skin had been exposed by

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our lack of hair, but why did we lose our hairy sun-protection covering? The most convincing theory is based on ectoparasites – lice, ticks, and flies. During our many years in caves, these critters attached and bit us and transmitted disease into our blood.

A widespread view of host-parasite coevolution points to host illness as a potential liability for the pathogen. Pathogens need host mobility to reach uninfected individuals and if the illness caused by invasion of the host by the parasite is too robust it may reduce further disease transmission. As Ewald states, the modern view of host-parasite coevolution "differs from the traditional view, however, in weighing these costs of intense exploitation against the competitive benefits that the pathogen accrues from the exploitation. The modern view proposes that high virulence can be evolutionarily stable if the costs incurred by parasites from the host damage are particularly low and/or the benefits obtained by the parasites from exploitation are particularly high" [1]. If the host stays healthy enough to live, even if immobilized, and this has little adverse effect on transmission, then pathogen benefits outweigh the risks. Parasites that do not rely on host mobility for transmission should evolve to be more virulent than those that do rely on host mobility. Therefore the diversity of virulence found among host-parasite associations can be tied to modes of transmission instead of variation in the state of parasite adaptation to the host. Each new invasion is a trade-off between the benefits of increased host exploitation and the costs of reduced host mobility.

As far as host protection, the skin and its immunological contents does a superb job of protecting us. The melanocyte, a tiny structure (source of melanin), is one of the most important parts of the human body for many reasons, including skin color, sun protection, and cultural determination. Many skin diseases can engender heavy loads of social and psychological stress, but those with pigmentary alterations are often the most devastating. We have racial discrimination, wars, and other haunting acts of violence and evil in society prompted by perceptions about skin color [2].

The melanocyte provides energy, protection, and the color of our skin and eyes. Melanocytes live in the top layer of the skin and create melanin, which is a widely available substance in nature, even seen in plants and fish. The primary role of melanin in the human body is to act as a natural sun block, absorbing ultraviolet radiation from the sun and quickly converting it into harmless heat. How effective is melanin as a photoprotectant? The photochemical properties of melanin transforms the harmful UV energy via "ultrafast internal conversion" and enables melanin to dissipate more than 99.9 % of the absorbed UV radiation and prevents the indirect DNA damage that is responsible for the formation of malignant melanoma and other skin cancers.

How does melanin and skin color work? Imagine you had a genetic paintbrush and you could mix the colors together, but you only had two colors – pheomelanin (red) and eumelanin (very dark brown). You make your choices on the quantity and type of melanin given, determined by a handful of genes. One copy of each of these genes is inherited from each of our parents and each gene comes in several different versions known as alleles. People with dark skin need more melanin pigment compared to light skinned persons. Differences in the number, size and nature of pigment cells, containing pigment granules called melanosomes, determine the many different shades of skin color. Europeans have fewer, smaller and lighter melanosomes than those from people of West Africa [2].

Are there exceptions to the skin and nature rule? Yes. And perhaps it can best be illustrated in the Inuit people of the American Subarctic who live in a far northern latitude but have moderately heavy skin pigmentation. The pigment decreases vitamin D production but they eat loads of Vitamin D packed fish and sea mammal blubber to compensate. Since the Inuit have only inhabited their northern land about 5,000 years, the lower melanin production may not yet have been selected for by nature. Genetics is the change of last resort, and if they can still eat the fish and blubber, they are OK for now.

Skin disease such as vitiligo (chronic) or acute (cellulitis) are influenced by the micro-environment and micro-evolutionary processes. Chronic disease such as albinism can have extensive cultural effects. Many Native American and South Pacific tribes believed that human beings and animals with albinism were messengers from divine entities. Some saw them as good omens and treated them with utmost respect. Others viewed their presence as a manifestation of wrongdoings within the tribe. In Africa, life has always been particularly difficult for people with albinism. Widespread poverty and ignorance about the condition deprives these individuals of much-needed protection from the burning sun. As a result, many die prematurely from skin cancer. Even if they do manage to avoid the strong sunlight, it often means a life of virtual solitary confinement and prohibition from participating in the daily activities of their kinship group. Skin color, disease, or irregularity can effect social position, self-esteem, and a person's opportunities in every society [2, 3].

Could there be any protective utility in skin disease? Perhaps in psoriasis there is some hidden adaptive function that carries a genetic survival advantage. If the same genes that trigger psoriasis also control the intensity of bacteria invasion, then perhaps the combined 1–2 punch of an enhanced inflammatory response and thickened keratin layer allowed those with the psoriasis-predisposing genome to have survival advantage. The natural process of desquamation, where the skin rids itself of excess layers of keratin, is heightened in psoriasis and may provide a helpful response to discourage colonization of the skin's surface by undesirable microbes and maintain integrity of the skin by shedding faster than colonization can get traction.

Other protective roles for psoriasis can be seen with cutaneous tuberculosis, a disease that can bring on horrible facial destruction. Psoriasis first came to widespread attention in the medical community in the mid-nineteenth century, coincident with a high prevalence of cutaneous and systemic tuberculosis. As many researchers have reported, cases of patients with both skin diseases were essentially absent. Do psoriatic carriers protected from tuberculosis have a survival edge against the more disfiguring cutaneous TB? If the psoriasis carrier could be protected against TB, the predisposing psoriasis genotype could survive. Trials and research with the new biologic drugs that now blanket the medical journals and TV commercial airways have proven that psoriasis patients have inherent T-cell populations that indicate activated immune systems. And one of the main contraindications for the use of any psoriasis-halting biologic is an active systemic TB infection [2].

Both chronic and acute diseases often reflect a change in the "wildness" of our lives. We have had drastic changing relationships with the rest of nature, including the lives that live on us, our mutualists and our predators, and we have cleansed ourselves into a hygienic and antibiotic-overloaded crossroads. As Rob Dunn writes, "We have options. One, the one we are headed toward, is a world in which our daily lives are more removed from nature (which is itself increasingly impoverished) and we are sicker, less happy, and more anxiety-ridden for it. In this world, we treat our problems with more and more medicines in an attempt to use chemicals to restore what we miss from other species." By looking at skin, hair, and ectoparasites as part of human variation, we see that micro-evolutionary processes have widespread consequences for our health and quality of life [4].

From the skin to the bigger picture of human nutrition, type 2 diabetes has grown to the point that researchers have come to speak of "diabesity," the growing pandemic of diabetes associated with obesity [5]. Although it was once referred to as "adult onset diabetes" it is now seen in children and young adults as well and the chronically high levels of blood glucose may wreak havoc on the pancreas, eyes, nerves, heart, and blood vessels. The growing epidemic of diabetes in certain populations of Native Americans have led select anthropologists to propose the "thrifty gene hypothesis" and the "New World syndrome." These Darwinian explanations suggest that the feast-or-famine existence of the human past in certain populations favored a genetic propensity to store food energy effectively and release insulin quickly. The Native Americans, however, were only the leading edge of what is now a worldwide health problem due to an obesity-and-diabetes-promoting environment of energy-dense foods and decreased physical activity [6, 7].

As with most events in the human body over the last 12,000 years, the cultural input and political economy has had the greatest effect. The spiral of inactivity leading to obesity and further inactivity is an increasingly virulent childhood problem throughout America; the pandemic of television and video games as major leisure activities is a chief factor in children's decreased activity and overweight status. As noted in the book chapter The Ecology and Economics of Nutrition [5], a study of families living on the impoverished east side of Buffalo, for example, showed extraordinarily high rates of overweight and obese children (age 6–12). The factor that contributed most to children's obesity was having an obese parent. Another key variable associated with children's obesity was having multiple television sets in the household. A turned-on TV in the room resulted in fewer hours of sleep for the child, a syndemic factor in obesity [8].

In Elizabeth Kolbert's books *Field Notes from a Catastrophe: Man, Nature, and Climate Change* [9] and the Pulitzer Prize winning *The Sixth Extinction: An Unnatural History* [10], Kolbert notes that by burning fossil fuels and warming our planet's atmosphere, oceans, and the climate, acidifying our waters, and generally wreaking havoc on everything we touch, we are pushing millions of species into extinction. Her revealing and disturbing dispatches about human-propelled crises noted in her world travels, including the Amazon rain forests and the Great Barrier Reef, herald a profound urgency for scientific intervention to prevent a forthcoming cataclysmic result. Scientific American called the book "this era's galvanizing text" and indeed it sets the bar quite high for us mere mortals trying to craft good creative non-fiction. Most of all, if we are to continue to exist, however natural or modified we are, Kolbert's work pushes us to make important decisions about our future.

We as humans have choice and agency to decide on the best path. In closing, I include the words of Leonard Mlodinow, who wrote, "Our best hope for a better future, then, is through the development of values that encourage caring for one another, cherishing knowledge and learning, preserving natural resources, and minimizing harm to our environment. It is only this kind of evolution, which is cultural rather than biological in nature, that can save us" [11].

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Chapter 6

Acute vs. Chronic Illness: How Do We Decide What to Treat or Eliminate?

What happens when someone gets sick? Most people would answer, "you get sick, you get treatment, and you get better." But for 133,000,000 Americans the answer is "you get sick, you get treatment, you never get better." These are the people with chronic illness. Chronic diseases are now the major cause of death and disability worldwide. Noncommunicable conditions, including cardiovascular diseases (CVD), diabetes, obesity, cancer and respiratory diseases, now account for 59 % of the 57 million deaths annually and 46 % of the global burden of disease.

Although many of these are not spoken but assumed, here are some of the common responses we often get from patients with ongoing medical problems:

Why me? Why now? There is so much I haven't done yet. Is this the beginning of the end? I'm not ready. What did I do to deserve this disease? I must be a bad person. This must be a punishment. Did I cause this disease? If only I had exercised more, eaten better, stopped stressing, etc. Will I lose my independence? My mind? My life? My hopes and dreams? Why has society not put more emphasis on our health?

I suggest the following:

Why not me? Why not now? Are there things I can still do? Am I still breathing and thinking and reading? Is anyone ever ready to have a chronic illness? Can all this wondering, worrying, and blaming change what's happening right this very second? What can we do to improve our collective health?

The task of treating and responding to chronic disease may seem counter-intuitive, because so much emphasis in current healthcare is on

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repair and restructuring and cosmetics. But with the shortage of those that provide primary care and help for chronic illness, it is urgent that those suffering are given a fair chance to succeed in the fast-changing world of modern healthcare. Modern medicine is more about chronic care than acute care—even AIDS has entered the realm of chronic care.

The following are facts related to chronic diseases from the World Health Organization:

> Chronic diseases are now the major cause of death and disability worldwide. Half of these (17 million annually) are CVD, the majority heart disease and stroke. Five of the top 10 selected global disease burden risk factors identified by World Health Report 2002: reducing risks, promoting healthy life - obesity, high blood pressure, high cholesterol, alcohol and tobacco – independently and often in combination, are the major causes of these diseases.

A relatively few risk factors – high cholesterol, high blood pressure, obesity, smoking and alcohol – cause the majority of the chronic disease burden. A change in dietary habits, physical activity and tobacco control, have a major impact in reducing the rates of these chronic diseases, often in a relatively short time.

Heart attacks and strokes kill about 12 million people every year; another 3.9 million die from hypertensive and other heart conditions. More than one billion adults worldwide are overweight; at least 300 million of them are clinically obese.

About 75 % of CVD can be attributed to the majority risks: high cholesterol, high blood pressure, low fruit and vegetable intake, inactive lifestyle and tobacco. Sustained behavioral interventions have been shown to be effective in reducing population risk factors. A few, largely preventable, risk factors account for most of the world’s disease burden. Chronic diseases are the major cause of death and disability worldwide, and increasingly affect people from developing as well as developed countries. This reflects a significant change in diet habits, physical activity levels, and tobacco use worldwide as a result of industrialization, urbanization, economic development and increasing food market globalization.

Up to 80 % of cases of coronary heart disease, 90 % of type 2 diabetes cases, and one-third of cancers can be avoided by changing to a healthier diet, increasing physical activity and stopping smoking.

Reviewing these facts from the WHO should awaken you to the choices you have. We live in a world between expectation and reality; our goal is to provide awareness of the problems and look at solutions for this huge societal burden.

We have a huge health care disparity. The poor, not having the money for routine screenings or to even have a regular family doctor, end up using the emergency room as their primary source of care. Because of this, they wait until a health issue is critical enough to warrant attention in the emergency room. By the time they seek help, there may be permanent damage that could have been prevented. (obesity, heart disease, diabetes, cancers).

Time's arrow only moves in one direction—forward—and chronological aging takes a toll on all of us, especially visible on our most recognizable features. A rising tide of boomers are arriving daily at the shores of older age and demanding more help for the chronic illnesses.

Chronic illness is a complex problem in our society. The expectations for a quality life are higher than ever before, and yet we are burdened with the same body that is prone to infirmities. More than 10,000 people are turning 50 each day, and most boomers believe their best years are still ahead. And many of those 50+ will either carry chronic illness into their remaining years or develop chronic illness problems as they age.

Chronic illness began to be addressed in the 1950's after the widespread use of antibiotics, immunizations, and public health measures helped eradicate many of the acute illnesses that were a constant threat to the majority of the population. We are producing fewer primary care and geriatric physicians with the broad-based knowledge to care for those with chronic illness. The issue of chronic illness, its enormous weight on our society, with its financial, social, and spiritual weakening of the core of our collective fiber--is just now being addressed with a passion that shines a light on the need to learn more and seek clear and viable solutions.

Advances in Medicine

People are living longer yet there are more people with chronic illnesses than ever before. Advances in medicine allow have made it easier to diagnose diseases earlier. When a disease is diagnosed earlier, patients and doctors can work proactively to minimize long-term damage and even death. A patient with adult onset diabetes can now monitor their blood sugar several times a day, take medications to control the disease and make lifestyle changes. A patient with a bad lipid ratio can exercise more, modify their diet, and take medications to change the levels of bad (LDL) and good (HDL) fats in their blood stream. A century ago, doctors did not have the sophisticated diagnostic tests that they have today and very few treatment options were available. Autoimmune diseases like multiple sclerosis and lupus were death sentences. With better, earlier diagnosis and more treatment options these diseases are life sentences. In many cases the same can be said for HIV/AIDS. So, earlier diagnosis and better treatment (but not cures) result in more and more people who live with chronic illnesses that were once considered fatal.

Genetics and Medical Advances

When a new baby arrives in a family, everyone looks for resemblances to other family members. She has her father's eyes, her grandmother's nose, her uncle's chin and her mother's hair are the kinds of things family members say when looking at a new baby. There are family resemblances that we can see, evidence of inherited genes, and then there are family resemblances that no one and whose influence no one can predict. Genes can predispose people to all sorts of diseases and conditions from diabetes to heart disease, from autoimmunity to cancer. Genes are pieces of DNA that have instructions on how to make the proteins the body needs to function. Genes affect inherited (hereditary) traits, or those that are passed on from a parent to a child, such as hair color, eye color, and height. They also affect whether a person is likely to develop certain diseases, such as cancer.

In some diseases, like sickle cell anemia, both parents must carry the gene and pass it on to the child. In other diseases, such as autoimmune diseases, the child may inherit a predisposition to the disease but may or may not develop active disease. With some cancers a person might be genetically predisposed with a high likelihood of developing cancer. Aging, advances in medicine and genetics are just two pieces of the complex puzzle that is responsible for the prevalence of chronic disease.

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Lifestyle

Lifestyle plays a significant role in the development of chronic illness. As agriculture became increasingly automated and scientific, fewer people needed to do the hard physical labor of providing food for themselves and others. The industrial revolution saw humans being replaced by machines resulting in an increase in factory work over farm work. The late twentieth century saw computers and technology replacing factory production resulting in as increase in information related work over production related work. Gradually, over just about two centuries, we have seen a shift from active physical work to less active physical work in manufacturing to an even less physically active emphasis on information and technologically based means of earning a living. Just as gradually, we have become sedentary people.

The shift from farm to factory to technology has not only changed our relationship with work, it has changed our relationship with food. Gone are the days when we ate in synch with the seasons of the harvest. Thanks to modern agribusiness we can have any food we want any time we want. Gone are the days when people harvested, prepared and ate the food in pretty rapid sequence. Now we have "convenience foods" that are often stripped of their original nutritional value in processing and preserving and then have a few "nutrients" tossed back in to lead us to believe they are nutritionally superior. Convenience reigns supreme. Salt, sugar and fat are generously added along with chemical colors and preservatives to make the food desirable. The loss of nutrients and addition of things that do not belong in our food rob our bodies of the things that were intended for our nourishment and health.

Work had changed and recreation has also changed. Where once young people played games outside from the time they came home from school until the street lights came on signaling a return to home, today many young people spend the recreational time playing video games, hooked into their iPods, texting, or living in the world of social networking. Even infants and toddlers are placed in bouncy seats and are parked in front of videos of Baby Einstein and Noggin. Of course they can develop their brains, but they also need to develop their bodies. It is the development of the whole person that wards off the development of chronic disease.

The consequences of being sedentary people and disconnected with our healthy food sources are a host of chronic conditions ranging from diabetes to heart disease to obesity with all their consequences. The societal and scientific response has not been to change lifestyle but to medicate and surgically treat the consequences of these lifestyle changes. The response is good business. It does not require people to make lifestyle changes, but rather creates another sedentary business making and marketing expensive chemical solutions.

The shift from acute to chronic disease over the last several decades has been dramatic. Lung cancers (along with trachea and bronchus cancers) caused 1.5 million (2.7 %) deaths in 2011, up from 1.2 million (2.2 %) deaths in 2000. Similarly, diabetes caused 1.4 million (2.6 %) deaths in 2011, up from 1.0 million (1.9 %) deaths in 2000. In chronic illness many factors contribute to the cause, the cause may be unknown, diagnosis is more difficult and often the goal of treatment is to manage symptoms and prevent further damage.

Aging

People are living longer than at any other time in history. In just one century we have seen a nearly 30 year increase in the number of years we can expect to live. The life expectancy of someone born in 1900 was 46.3 years for males and 48.3 years for females. By 1950 those figures jumped to 65.6 years for males and 71.1 years for females. By the year 2000 life expectancies climbed even higher to 74.3 years for males and 79.7 years for females.

We fail when we sanitize and make metaphors from death and illness. We often keep death and illness from young people for fear of upsetting them. This adds to the notion that we are invincible. Young people, who are in the best position to make choices that may prevent health problems are the very people who believe they need to make changes the least. We need more education and an honest approach to suffering and death.

No one lives forever. The longer we live, the greater the likelihood that something will go wrong. The higher percentage of older people in our society, the higher the percentage of chronic illnesses and conditions we can expect to see. The 2000 United States Census identified Baby Boomers, those born from 1946 through 1964, as making up 28 % of the U.S. population. Those people are now 15 years older! In the decade between 1990 and 2000, the 50–54 year olds group experienced the largest percentage growth in population, 55 %. The second fastest growing group was the age group 45–49, which experienced a 45 % increase. The third fastest growing group in that decade was 90–94 year olds, which increased by 45%!

At first glance, the graying of the population would seem to be the culprit in the high numbers of people with chronic disease. We commonly accept the notion that as we get older, we get sick and frail. We expect an inevitable decline. Those few peppy centenarians we hear about in human interest stories at the end of the nightly news are just the exception that proves the rule! As noted in detail in the chapter on aging, although it is true that old age includes a diminishing of certain immune responses, it is in itself not a disease. The 80+ population is the fastest growing segment of the aging population, and we would be wise to study the success of their longevity. Most of the oldest old die from TMB’s—too many birthdays—and therefore the idea is to die young as late as possible.

Carcinogens and Chronigens

What should we focus our limited resources on? Given that disease keeps us inventive, what diseases should we keep?

One of the key factors to our future health will be how to deal with carcinogens and *chronigens*. We have known for many years about carcinogens and have gained a rapid understanding of endocrine disruptors. What are chronigens? Any chemical trigger that results in chronic illness is a chronigen.

When interviewing Linda Reuscher, a leading expert in chronic illness, she stated, "Plastic is everywhere and it's a problem. Every school child knows that plastic water bottles and bags are piling up in landfills and that they don't break down for thousands of years. Try to find a piece of food that has never touched plastic. Hard, isn't it? What's the problem with plastic anyway? Plastics leech chemicals into the food and beverages with which they come in contact. When plastics are heated they release even more molecules. Particularly troublesome is bisphenol A (BPA)."

The Food and Drug Administration and the Environmental Protection Agency measure toxins and decide, based on their research, how much of a particular toxin we can handle and not get sick. What they fail to do is consider what Janet Jackson-Nakazawa (in her book *The Autoimmune Epidemic*) calls the barrel effect. Too many assaults over time cause the barrel to overflow and we get sick, and so does the Earth. When the delicate balance is upset just a little, we self-correct. When the delicate balance is bombarded it is more difficult to make things right.

Our food contains toxins, many of which are chronigens. The higher up the food chain you go, the more concentrated the toxins: mercury in fish, more mercury in larger fish that eat the little fish; pesticides in corn, more pesticides in animals that eat the corn. Farm animals are routinely given growth hormones (bovine growth hormone, diethylstilbestrol) and antibiotics. Toxins in air and water nurture the plants and animals further increasing the toxic load.

When we drink a glass of water we are drinking down chemicals such as chlorine, pesticides, heavy metals, and even pharmaceuticals. When we mentioned this to a colleague, she said, "Oh of course. I guess people sometimes flush pills down the toilet." Her eyes widened as we explained that not only are some pharmaceuticals disposed of in that way, but that when people take medication, it may not be fully metabolized and some of it passes through the body, ending up in our water supply. Filtering does not remove the drugs. So that water you used to make your morning coffee may well contain hormones, contraceptives, antidepressants, tranquilizers and many other medications. Adding insult to injury is the fact that as you go higher up the food chain, these drugs become more concentrated in your food as well.

The Future

Much can be done to prevent the disfiguring effects brought on by nicotine and alcohol, excess weight, mobility and exercise difficulties, dysfunctional nutrition, improper hygiene, lack of immunizations, poor reading and comprehension skills, inadequate cosmetic repair, and many other problems. We have highly effective therapies, a plethora of information about health on the internet, and more prevention and treatment modalities than ever before.

What drugs that may now be considered experimental are on the horizon and can be used in the near future for chronic illness? Will boutique medicine offering genetic treatments be offered in the next 10 years? What are the ethical implications of chronic illness? If you knew via genetic testing that your child may develop systemic lupus or severe arthritis, would you consider genetic manipulation to provide future protection? What are the religious, philosophical, and moral imperatives involved with chronic illness? Could there be any beneficial aspects of having a chronic illness that can be detected, genetically manipulated to enhance our immune systems while eliminating the corresponding harsh symptoms of the illness? As we move forward from the world of The Last Natural Man, what will we choose to prevent, repair, and focus on as a society?

Chapter 7

The Last Natural Brain

> The human brain had vast memory storage. It made us curious and very creative. Those were the characteristics that gave us an advantage - curiosity, creativity and memory. And that brain did something very special. It invented an idea called 'the future.' ~ David Suzuki[1]

The work of the brain would be easy if we knew what we needed to remember or understand in the future. Life is full of surprises – new people whom we need to know, names we have to remember, problems we try to solve.

To a creationist, the brain as God's masterpiece seems self-evident: a summation of motor synapses and sensory stimuli, infused with the most important emotions of all – faith, hope and love; the least copy-able of God's own artworks. To a computer-programmer, this vision may seem a gimmick, a concept that has the blitheness of ignorance.

In an interview published in The Guardian[2], the celebrated scientist Stephen Hawking said:

> I regard the brain as a computer which will stop working when its components fail. There is no heaven or afterlife for broken down computers; that is a fairy story for people afraid of the dark.

The idea that the brain, once its blood supply has ceased, simply degenerates into nothingness is both stirring and frightening. For human beings

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[1] http://www.brainyquote.com/quotes/authors/d/david_suzuki.html#M5YKPjueO2ZAgwfE.99 accessed Dec 25, 2015.

[2] Ian Sample, Science Correspondent. The Guardian. 15 May 2011. Stephen Hawking: 'There is no heaven; it's a fairy story' http://www.theguardian.com/science/2011/may/15/stephen-hawking-interview-there-is-no-heaven accessed Dec 25, 2015.

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drunk with an engorged quest for immortality, the search for a 'human computer' to replace or replicate our brain is ongoing. But is it possible?

About, two decades ago, in 1994, Penrose wrote[3]:

> As yet, no computer-controlled robot could begin to compete with even a young child in performing some of the simplest of everyday activities: such as recognizing that a colored crayon lying on the floor at the other end of the room is what is needed to complete a drawing, walking across to collect that crayon, and then putting it to use. For that matter, even the capabilities of an ant, in performing its everyday activities, would far surpass what can be achieved by the most sophisticated of today's computer control systems.

Scenes from films like 'Blade Runner' and 'Terminator' featured intelligent bioengineered 'replicants' whose brains are indistinguishable from human thought, but academics have been long frustrated by the inability to replicate a human brain's analytical power.

I met Garry Kasparov, considered one of the greatest chess grandmasters at an international ideas conference called THiNK, when we were both asked to sign copies of our books at the store they had set up for speakers' books — Garry was signing copies of *How Life Imitates Chess: Insights into life as a game of strategy*[4] and I was autographing copies of my *Skin: A Biography*[5]. That was the biggest book-signing I've ever had to do — 250 copies one after the other.

'You like chess?' I was lured out of the monotony by Garry's voice. He had been leafing through my book and found a passage featuring Bobby Fischer, the late chess prodigy.

> Bobby Fischer, towards the end of his life, became reclusive, neurotic, paranoid and 'stateless', and Iceland had offered him residence after the US refused to allow him entry post a trip to Japan. In his prime, Fischer had been obsessive about chess and had admired Marcel Duchamp, a French artist, who gave up art for chess. Duchamp had described an opening called trebuchet or 'the trap'. But his favourite chess position was of an endgame called the Lasker–Reichelm position: a rare and unique position where black cannot win, but at best delay events.

'My dad used to play tournaments,' I replied. 'I played as a child with him, but not later on.'

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[3] R. Penrose. *Shadows of the Mind*. Oxford: Oxford University Press. 1994 page 45.

[4] Garry Kasparov with Mig Greengard, *How Life Imitates Chess: Insights into life as a game of strategy* (Arrow Books, UK, 2008).

[5] Sharad P. Paul. *Skin: A Biography* (4th Estate, 2013), p. 78.

In his prime as World Chess Champion, Kasparov had famously played against an IBM supercomputer, named 'Deep Blue'. A team of computer and chess experts recalibrated the machine between games, while Kasparov reprogrammed his own brain. The first match was played in February 1996 in Philadelphia, Pennsylvania. Kasparov won 4–2, losing one game, drawing in two, and winning three. A rematch took place in 1997, with Deep Blue winning 3½–2½. I asked Garry about what it was like to play a computer at chess — surely a computer was capable of calculating possible moves faster than a human?

'The best way to beat a computer is to play *unlike* a computer,' Gary said. 'Which is why Carlsen will win this year's chess championship . . . and why Fischer was so good.' I opened Garry's book and read: "… ordered systems lose less energy than chaotic systems." If our pieces work together they can better transform one advantage into another without losing quality. This theory of 'ordered systems' conserving energy and 'pieces working together' to create an advantage is a good analogy to explain the functioning of the human brain and memory.

One of the problems thus far has been that in medicine, we have simplified the brain into modules – physicians have insisted in dividing up the brain into well-defined anatomical regions – frontal lobe for personality, temporal lobe for memory etc., theories that we know are problematic when we survey the evidence. Just because computers need memory, it seems convenient to locate a 'memory module' in the brain. Megan Erickson puts it elegantly[6]:

> The brain is not a storage dump, and consciousness is not a place. Synapses are also far more complex than electrical circuits. Neither processing speed nor short term memory capacity are fixed, whereas RAM is.

We measure computers based on storage and speed, yet even an average human brain shades a computer when if comes to efficiency. Writing in the *Scientific American*, Mark Fischetti notes[7]:

> The world's most powerful supercomputer, the K from Fujitsu, computes four times faster and holds 10 times as much data. And of course, many more bits are coursing through the Internet at any moment. Yet the Internet's servers worldwide would fill a small city, and the K sucks up enough electricity to power 10,000 homes. The incredibly efficient brain consumes less juice than

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[6] Megan Erickson. "The Electronic Brain? Your Mind Vs. a Computer." http://bigthink.com/re-envision-toyota-blog/the-electronic-brain-your-mind-vs-a-computer accessed Dec 25, 2015.

[7] Mark Fischetti. Scientific American. Nov 1, 2011. "Computers versus Brains."

> a dim lightbulb and fits nicely inside our head. Biology does a lot with a little: the human genome, which grows our body and directs us through years of complex life, requires less data than a laptop operating system. Even a cat's brain smokes the newest iPad—1,000 times more data storage and a million times quicker to act on it.

How does the ancient brain beat the power of modern computers? It is the battle of the analog *vs.* digital – humans brain store information as varying threads and 'learn' and evolve based on previous experiences; a computer by contrast sees memory as a binary collection of ones and zeroes. Scientists working in this space of artificial intelligence now realize that storing memory as varying threads of information, rather than as binary digits is the key to making computers 'more human.'

Memory is everything when we choose a computer, yet the capacity to remember is the least important in selecting a mate as a human companion. When we go to the computer store, devices tout memories of 4GB or 16GB of RAM (Random Access Memory). RAM may help a computer multi-task but any arrest in the power supply leads to a rapid unraveling of memory (at least until the last 'auto-save'!). Enter memory-resistors, or 'memristors' – electronic components where electrical resistance is not constant as in standard resistors, but is determined by the history of the electric current that has previously flowed through it. In other words, a memristor "remembers" like a human brain. Researchers working at the Royal Melbourne Institute of Technology (RMIT) and the University of California in Santa Barbara claim to have constructed the world's first electronic memory cell that effectively mimics the analog process of the human brain – and with it comes the possibility and peril of a truly bionic brain. However, there exist some significant hurdles – when it comes to memory, speed alone isn't the problem – artificial intelligence (AI) will need to come up with new ways to match the 2C's of brain function – complexity and consciousness.

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Perhaps medical neuroscience has been slow to move towards 'singularity' due to the constraints of a medical model, or the differences between biological and technological concepts of the brain. For a start, if the human brain could be re-created, then medicine would have to be more inclusive, and couldn't inflict the prices it does on the premise of citizenship of a guild or cartel. The world of computer science is inherently less bureaucratic by nature, but also it couldn't care less about things like difficulty or danger that an artificially intelligent world would bring.

The concept of Singularity was first espoused by Vernon Vinge, from the Department of Mathematical Sciences of San Diego State University, to mean 'the imminent creation by technology of entities with greater than human intelligence.' Somewhat chillingly (for natural humans), in this essay written in 1993, Vinge wrote[8]:

> Within thirty years, we will have the technological means to create superhuman intelligence. Shortly after the human era will have ended.

However, people like Ray Kurzweil, proponents of 'singularity' theorize that computers shall exceed human capacity for thought fairly soon. In his book, *The Singularity Is Near: When Humans Transcend Biology* (Viking Press, 2005) Kurzweil creates a vision of intelligent nano-robots integrated into our bodies, our brains, and our environment, with a capability to eradicate pollution and poverty, offering the new artificial man extended longevity, while enjoying the sensory stimulation of a full-immersion virtual reality (think movies like "The Matrix" or "Being John Malkovich"). Kurzweil sets the date for this dramatic and disruptive transformation into a new human species as 2045, a hundred years after the end of the Second World War – during that year, the non-biological intelligence created will be one billion times more powerful than all human intelligence today.

Indeed, the world of nanotechnology is progressing rapidly. Microscopic robots can be placed inside human organs to give us an inside-knowledge of both brains and blood vessels. In his book, Kurzweil feels that for Singularity to occur, there has to be a confluence of three scientific streams – the three great overlapping technological revolutions that go by the letters "GNR," that stands for genetics, nanotechnology, and robotics. Genetic sequencing has also become faster and cheaper – sequencing the HIV virus took over a decade; recently SARS virus was sequenced in a month. This is about the last natural man playing God – creating a new species in man's own image, using the power of science with one difference from the last time around – the new bionic humans will no longer be in the shadow of their creators. Kurzweil does not see hardware requirements as a barrier. In fact, in an interview[9] about his book on Singularity[10], Kurzweil describes the computing power of the brain and computers thus:

> We can break this down further into hardware and software requirements. In the book, I show how we need about 10 quadrillion (1016) calculations per second (cps) to provide a functional equivalent to all the regions of the brain. Some

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[8] Vernon Vinge. "The Coming Technological Singularity: How to Survive in the Post-Human Era." Proceedings of a symposium cosponsored by the NASA Lewis Research Center and the Ohio Aerospace Institute; held in Westlake, Ohio, March 30-31, 1993.

[9] Questions & Answers. Ray Kurzweil. The Singularity Is Near: When Humans Transcend Biology. Viking Press. USA. 2005. http://www.singularity.com/qanda.html accessed Dec 25, 2015.

[10] Ray Kurzweil. The Singularity Is Near: When Humans Transcend Biology. Viking Press. USA. 2005.

> estimates are lower than this by a factor of 100. Supercomputers are already at 100 trillion (1014) cps, and will hit 1016 cps around the end of this decade. Several supercomputers with 1 quadrillion cps are already on the drawing board, with two Japanese efforts targeting 10 quadrillion cps around the end of the decade. By 2020, 10 quadrillion cps will be available for around $1,000.

There is not much dissent about the concept of Singularity anymore; the controversies are more focused on the actual algorithms. Speaking of algorithms, it is this ability of computer-scientists to view the human brain as a generator of various algorithms that creates the possibility of treatment of various disabilities.

At THiNK, I also met Moran Cerf, my good friend, who is now a Professor of neuroscience and business at the Kellogg School of Management and heads the neuroscience program at Northwestern University. Additionally, he holds a position at the department of neurosurgery, where he studies patients undergoing brain-surgery to examine behavior, emotion and decision-making. Moran sees the brain differently to me. I trained in medicine and have an interest in evolutionary biology and cutaneous oncology. Moran had a background as a computer hacker, before he studied neuroscience, and sees the brain as a generator of patterns – all emotions or dreams or maladies can be interpreted by studying brainwaves – once you've studied enough patterns, the 'big data' seems to make sense – for example, as we discussed the ability to mimic a human brain, Moran spoke to me about the interpretation of dreams. Using electrodes implanted in the brain he was able to decipher dreams – he could for example tell if you were thinking of an elephant (at the time we spoke, the technology was not refined to determine if the elephant was African or Asiatic).

In his lecture, Moran spoke about an experiment that featured a Chimpanzee and a robotic arm. The scientists implanted electrodes onto the motor cortex, over an anatomical region known to signal arm and hand movements. These electrodes, each connected to neurons that were wired to the brain, were also linked to a computer. There were plenty of food treats in the rooms – grapes, bananas etc. It didn't take a lot of time before the ape realized that the robotic arm was able to read brain signals, and therefore could be controlled by thought. Within a few days, the monkeys needed no help. They sat stationary in a chair, repeatedly manipulating the arm with their brains to reach out and grab grapes or nuggets of food dangled in front of them. Imagine the useful of thought-control for physically-disabled patients.

Writing about a similar experiment in *Nature*[11], Dr. John F. Kalaska, a neuroscientist at the University of Montreal, feels that as this technique is refined further, scientists might even discover areas of the cortex that allow more intimate, subtle control of prosthetic devices:

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[11] John Kalaska. Neuroscience: Brain control of a helping hand. *Nature* 453, pages 994-995 (19 June 2008).

> Such controllers would allow patients with severe motor deficits to interact and communicate with the world not only by the moment-to-moment control of the motion of robotic devices, but also in a more natural and intuitive manner that reflects their overall goals, needs and preferences For example someone paralyzed or in an institution because of mobility issues could order a robot to provide food or coffee by using thought-waves. The technology is here. Now.

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In the past, *Drosophila*, the fruit fly, was the most studied 'model organism' in genetics and biology. This was because it is hardy, easy to care for, breeds quickly and lays many eggs. In 1965, Sydney Brenner, mooted *Caenorhabditis elegans*, the non-parasitic nematode worm, as a new model organism for studying organ development, cell death, behavior and many other biologic processes. Brenner had obtained a culture of the Bristol strain of this worm from Ellsworth C. Dougherty (then in the Department of Nutritional Sciences at the University of California at Berkeley), who had worked extensively with the organism. Brenner, originally from South Africa and then director of the Laboratory of Molecular Biology (LMB) at Cambridge had written: "nearly all the 'classical' problems of molecular biology have either been solved or will be solved in the next decade." For his work on this worm, in 2002, the Nobel Prize committee honored Sydney Brenner with the Nobel Prize for Physiology or Medicine (along with John Sulston and Robert Horvitz). This soil worm had excited scientists as it had many attributes that made it a natural model for scientific study – for a start, it is barely over 1 mm in length, lives for approximately three days, feeds on easily cultivated bacteria such as E. coli and a single Petri-dish can hold over 10,000 of these critters. In its hermaphrodite form, it is even capable of reproducing itself. It is anatomically simple, with a body containing just over 1000 cells including a 302-cell nervous system.

C. elegans was the first multicellular organism to have its genome completely sequenced. The genome of this worm contains 97 million base pairs. This is about 3 % the size of the human genome, which has three billion base pairs.

Drawing a connectome is basically mapping all neural connections in the brain, and can be thought of as being similar to an electrical "wiring diagram". In 1986, the entire connectome of *C. elegans* was mapped, and as the genome had been mapped, science was much closer to completing the GNR triad needed to create an artificial brain. Therefore in 2011, a team of scientists from the US, Europe and Russia began the OpenWorm Project –

an attempt to build a complete artificial nervous system of this worm with the capacity to stimulate various actions i.e. an artificial *C. elegans*.

Researchers on the OpenWorm Project soon reached a philosophical crossroad. If they could replicate the nervous system of this creature and implant that ‘brain’ into another body, would that body behave like a worm? This was the very experiment they undertook – scientists took the connectome of a *C. elegans* worm and transplanted it as software into a Lego Mindstorms EV3 robot – what happened next? The Lego model robot began to behave exactly like the worm! Stimulation of the nose stopped forward motion. Touching the anterior and posterior touch sensors made the robot move forward and back accordingly. Stimulating the food sensor made the robot move forward. They now had a creature that behaved like a worm but was a Lego model (and therefore not as squishy). Slowly but surely science is wiggling towards Singularity.

It’s all very well messing about with a tiny nervous system, but if we were to build a truly human brain, could we control this being? After all human beings have 13 billion neurons with trillions of possible interactions. Many scientists indeed voice a fear of artificial intelligence taking over the world. The other possibility for an artificial brain is both frightening and exciting. Think about this: If the OpenWorm Project could be replicated, we would no longer be constrained by our organic bodies – physical forms that were the result of four billion years of evolution by natural selection. Life could become inorganic, powered by exact replicas of our own brains. This possibility was made more probable by funding from the European Union – in April 2013, it selected the Human Brain Project to be its scientific flagship, giving it a grant of more than €1 billion.

Even before the OpenWorm Project model, Henry Markram, a South African neuroscientist led the Blue Brain Project at the École Polytechnique Fédérale de Lausanne in Switzerland. Using a similar technique (as in the *C. elegans* research), his team began studying the neural networks of rat brains – with a goal of computer-based models that mirror the rat brain’s complex biological networks. “Technologically, in terms of computers and techniques to acquire data, it will be possible to build a model of the human brain within 10 years,” Markram has been quoted saying.[12]

Yuval Harari, debates the transition or rather our progress as a species from evolution by Natural Selection to evolution by Intelligent Design. He calls this ‘the greatest revolution in thousands of years of history, but also the greatest revolution in billions of years of biology.’ Harari, in *Sapiens: A*

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[12] Max Miller. Can Computers Be Conscious? Big Think. http://bigthink.com/going-mental/can-computers-be-conscious accessed Dec 25, 2015.

Brief History of Humankind writes about the many positive aspects of intelligent design[13]:

> The replacement of natural selection by intelligent design could happen in any of three ways. The first way is through biological engineering. Bio-designers could re-engineer the shapes, abilities and desires of organisms, in order to realize some preconceived cultural idea. There is nothing new about biological engineering, per se. People have been using selective breeding, castration and other forms of bio-engineering for at least 10,000 years. But recent advances in our understanding of how organisms work, down to the cellular and genetic levels, have opened up previously unimaginable possibilities. For example, scientists can today take a gene from a jellyfish that glows in a green florescent light, and implant it in a rabbit or a monkey, which starts glowing in a green florescent light. E. coli bacteria have been genetically engineered to produce human insulin and bio-fuel. A gene extracted from an arctic fish has been inserted into potatoes, making the plants more frost resistant.

Harari has a very hopeful view of intelligent design. But as a medical doctor, I am aware that medicine is often unpredictable, phenomena like the 'placebo effect' cannot be easily explained by computers. A computer can beat me hands down in predicting what percentage of my patients would respond to a particular medication, but could it deal with the imperfections and frailties of the human mind?

Max Pemberton, the author of *The Doctor Will See You Now* (Hodder and Stoughton, 2012) writes about an experiment conducted by the psychologist Ellen Langer in 1979[14]. A group of elderly men were taken to a 'reminiscence retreat' outside Boston. The first group was the 'control group' and spent a week simply reminiscing about the Fifties. The second group, however, was taken back in time and surrounded by objects from the Fifties and asked to behave as if it really was 1959. Over the week, something astonishing happened. The men stopped using their walking sticks, they began to walk faster and their posture improved. What this experiment demonstrated is that as humans we are more than genes and brains. We have a collective consciousness. Pemberton is skeptical that computer code could replace medicine. "Computers are a useful tool in treatment, but medicine is far too complex to be reduced to code," he says[14]. Like me, Pemberton is a medical doctor and this may only turn out to be wishful thinking.

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[13] Yuval Noah Harari. 'Sapiens: A Brief History of Humankind.' Chapter 20. Harper; 1St Edition (February 10, 2015).

[14] Max Pemberton. A computer can't compute the power of the human mind. The Telegraph. 29 April, 2013.

Technically it will soon be possible to create artificial versions of our brains and implant them into all kinds of inorganic models. Given a choice, you could take on any form that you wish. The question more to the point would be: What do you want to become? But with your brain and without your existing form, would that really be you?

When I visit Oxford University, I usually stay at Keble College. It is a lovely college and the last time I was there, I stayed in the Lewis Room, named after C.S Lewis. In 1945, Lewis penned *That Hideous Strength*: *A Modern Fairy-Tale for Grown-Ups*[15], as the final book in his theological sci-fi Space Trilogy, which was recently reviewed in Salvo magazine[16]. In its plot, a philosophy professor, Mark Studdock, gets caught up in a diabolical scheme to take over the world. The leader of the cult is the severed head of a criminal genius, kept alive by tubes and wires. "Don't you see," says one character, inviting Mark into the fellowship, "that we are offering you the unspeakable glory of being present at the creation of God Almighty?" This book was Lewis' foray into Transhumanism – Transhumanists speculate freely about becoming immortal by "uploading" their consciousness into computer brains with robotic bodies, something that is now becoming closer and closer to scientific reality.

***

In my view, there are two requirements for a brain to be truly human: the 2C's of complexity and consciousness.

The complexity of the human brain has been a barrier in facilitating rapid evolution. Chimpanzees, the apes closest to humans weigh about 20 % less than the average human, but the human brain is 250 % larger than that of a chimp. Given this, it was assumed that human genes that regulate brain development would evolve at a much faster rate than that of apes. In actual fact, the reverse is true. This is all to do with complexity.

You see in primitive creatures, the larger the brain, the more rapid the evolution – protein sequences in chimpanzees changed faster than genes from monkeys, which changed faster than those from mice. Writing in the influential scientific journal *PLOS Biology*, a team from the University of Chicago found that gene evolution in human beings has slowed. They noted[17]:

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[15] C.S. Lewis. That Hideous Strength (Space Trilogy, Book 3) 1945 Scribner; Reprint edition (May 13, 2003).

[16] Leslie Sillars. 'The New Religion of Computer Consciousness.' Salvo Magazine http://www.salvomag.com/new/articles/archives/science/sillars.php accessed Dec 25, 2016.

[17] University of Chicago Medical Center. "Complexity Constrains Evolution Of Human Brain Genes." ScienceDaily. 29 December 2006. www.sciencedaily.com/releases/2006/12/061226095421.htm accessed Dec 25, 2015.

> On the basis of individual neurons of the brain, humans may indeed have a far more active, or even more complex, transcription profile than chimpanzee …we suggest that such abundant and complex transcription may increase gene-gene interactions and constrains coding-sequence evolution.

This means that natural selection is no longer enough to code new advanced genetic sequences. For human populations to improve their "fitness", intelligent design needs to design new codes. Necessity may indeed be the mother of new inventions.

Let's examine consciousness for a bit. At a basic level, being conscious means 'being awake.' Therefore if your computer cannot wake itself up every morning, it cannot be conscious, right?

Michael Graziano is a professor of neuroscience at Princeton University in New Jersey. His latest book is *Consciousness and the Social Brain* (Oxford University Press, USA, 2013). In an essay titled, 'Build-a-Brain' he describes how human brains perceive objects. For example, if we were to look at a tennis ball bouncing, we would note its color, shape, how high it bounced, the variability of the bounce etc. Our brain constructs something like a dossier, a dataset that is constantly revised as new signals come in. This is what scientists refer to as the "internal model." However, if we were to ask a robot a few questions regarding the tennis ball, Graziano suggests that the conversation would go something like this[18]:

> We ask: 'What's there?'
>
> It says: 'A ball.'
>
> We ask: 'What are the properties of the ball?'
>
> It says: 'It's green, it's round, it's at that location.' It can answer that because the robot contains that information.
>
> Now we ask: 'Are you aware of the ball?'
>
> It says: 'Cannot compute.'

It is this lack of 'awareness' that differentiates a computer from a human. It is the inability to understand the abstract or imperfect relationships. However, people developing artificial intelligence view this as a technical or engineering problem rather than an emotional one.

Giulio Tononi at the University of Wisconsin-Madison has been trying to solve this problem of the mathematical theory of consciousness, dubbed the "Integrated Information Theory." Tononi feels one of the main aspects of human consciousness is the ability to learn from experience; the second is the ability to solve mysteries – everyday relationships are mysteries are they not (Men are from Mars, Women from Venus)? Tononi reckons that unless these problems are solved, a computer cannot be truly conscious and

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[18] Michael Graziano. Build-a Brain. https://aeon.co/essays/can-we-make-consciousness-into-an-engineering-problem accessed Dec 25, 2015.

Singularity will not be achieved. But what if humans could 'lend' a computer some conscious awareness? This has led scientists to develop brain-computer interfaces (BCI). In a first-of-its-kind study, engineers and neuroscientists in India and France recently demonstrated the viability of direct brain-to-brain communication in humans. They successfully transmitted information (words like 'hola' and ciao') via the Internet between intact scalps of two human subjects – located 5,000 miles apart. Explaining their methods in PLOS ONE, they say[19]:

> By using advanced precision neuro-technologies including wireless EEG and robotized TMS (trans-cranial magnetic stimulation), we were able to directly and noninvasively transmit a thought from one person to another, without them having to speak or write

One of the reasons consciousness has been elusive for otherwise intelligent robots is that consciousness (or to the philosopher, the psyche) is everywhere. Neuroscientist Christof Koch, chief scientific officer at the Allen Institute for Brain Science, talks about the theory of panpsychism – put simply, we are just a mind (or soul) in a world of minds. This was a theory espoused by thinkers like Plato and Spinoza, only to be sidelined by modern society's quest for empiric science. But a failure to infuse computers with consciousness has reignited this debate. According to Koch, consciousness arises within *any* sufficiently complex, information-processing system and the solution to Singularity may lie in us being connected. In an interview with *Wired* magazine[20] (rather appropriate, don't you think), he noted:

> The Internet contains about 10 billion computers, with each computer itself having a couple of billion transistors in its CPU. So the Internet has at least 10^{19} transistors, compared to the roughly 1000 trillion (or quadrillion) synapses in the human brain. That's about 10,000 times more transistors than synapses. But is the internet more complex than the human brain? It depends on the degree of integration of the Internet… For instance, our brains are connected all the time. On the Internet, computers are packet-switching. They're not connected permanently, but rapidly switch from one to another…

Therefore, consciousness = connectivity.

Therein lies the future. Technology now has the capability of making humans communicate via computers without using any of their traditional five senses. Genomes have been mapped. Artificial brains have been created for worms and mice that transmit their behaviors to inorganic hosts, even Lego models. We also have the capability to use our thoughts to control robotic bodies. Even if Singularity isn't here yet, we have reached a new level of human-machine interaction as a halfway measure towards achieving the ultimate goal. For now, this human-computer seems the immediate future and one that will help computers 'learn' our way. Will the future be dystopian and Utopian? Time will tell. However, I must say this – when I read Utopia I felt uneasy about the sameness of society portrayed therein. I am not worried about Singularity as long as artificial intelligence can be varied, moody, altruistic and joyful. Isn't life about celebrating differences?

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[19] Alvaro Pascual-Leone and others. "Conscious Brain-to-Brain Communication in Humans Using Non-Invasive Technologies" PLOS ONE. Published online August 19 2014.

[20] A Neuroscientist's Radical Theory of How Networks Become Conscious. WIRED magazine interview with Christof Koch. http://www.wired.com/2013/11/christof-koch-panpsychism-consciousness/ accessed Dec 25, 2015.

Over half a century ago, I.J. Good wrote about the dangers of artificial intelligence[21]:

> Let an ultra-intelligent machine be defined as a machine that can far surpass all the intellectual activities of any man however clever. Since the design of machines is one of these intellectual activities, an ultra-intelligent machine could design even better machines; there would then unquestionably be an "intelligence explosion," and the intelligence of man would be left far behind. Thus the first ultra-intelligent machine is the last invention that man need ever make, provided that the machine is docile enough to tell us how to keep it under control.

If you consider evolution by its dictionary meaning[22] – 'A gradual process in which something changes into a different and usually more complex or better form' – then the move from natural selection to intelligent design as the architect of biological progress is no different. The problems for human brains will be coping with mathematics and robotics with no specific purpose in mind. In a brave new world of independent thought, some human, some not – there is bound to be a conflict with the most human tendency of all: the need to control other beings. As Vinge noted in his essay[23] right through evolution, the next life form does not pay its dues to previous models:

> Any intelligent machine of the sort he (Good) describes would not be humankind's "tool" -- any more than humans are the tools of rabbits or robins or chimpanzees.

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[21] I. J. Good, "Speculations Concerning the First UltraIntelligent Machine", Advances in Computers, Vol 6, Franz L. Alt and Morris Rubinoff, eds, pages 31-88, 1965, Academic Press.

[22] evolution. (n.d.) American Heritage® Dictionary - English Language, Fifth Ed. (2011). http://www.thefreedictionary.com/evolution accessed Dec 25, 2015.

[23] Vernon Vinge. "The Coming Technological Singularity: How to Survive in the Post-Human Era." Proceedings of a symposium cosponsored by the NASA Lewis Research Center and the Ohio Aerospace Institute; held in Westlake, Ohio, March 30-31, 1993.

'Follow the money' may be an adage when it comes to solving complicated crimes, but it often gives us an idea where science is leading us. Recently, DARPA, the US Defense Advanced Research Projects Agency announced a $60 million challenge to researchers to create connections between the human brain and computers. Successful teams must create a neural engineering design system – with 'full-duplex interaction with at least 1,000 neurons – initially in regions of the human auditory, visual, and somatosensory cortex'[8]. The future of the computerized brain is here. One concern is however, security of such a system. Humans can be influenced; computers can be hacked. Therein lies another challenge.

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Chapter 8

Biomimicry

> Man masters nature not by force but by understanding. This is why science has succeeded where magic failed: because it has looked for no spell to cast over nature. Jacob Bronowski

Biomimicry and Our Future

A new future will need to include more creative and widespread use of biomimicry. Biomimetics or biomimicry is the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems. The terms biomimetics and biomimicry come from Ancient Greek derivation, including bios, life, mīmēsis, imitation, mīmeisthai, to imitate, and from mimos, actor. At the center of the action is the fact that living organisms have evolved well-adapted structures and materials over geological time through natural selection and biomimetics has given rise to new technologies inspired by biological solutions at macro and nanoscales.

A similar term is bionics, which is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. An example is a powered exoskeleton; bionic devices that can be strapped on as wearable robots to enhance the strength, mobility, and endurance of soldiers and paraplegics. In December of 2014, while visiting the company called ReWalk in Israel, (https://www.youtube.com/watch?v=yKt99lea1J0) myself and others in our group were privileged to observe the amazing and courageous people fitted with the device. As

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DOI 10.1007/978-3-319-42217-6_8

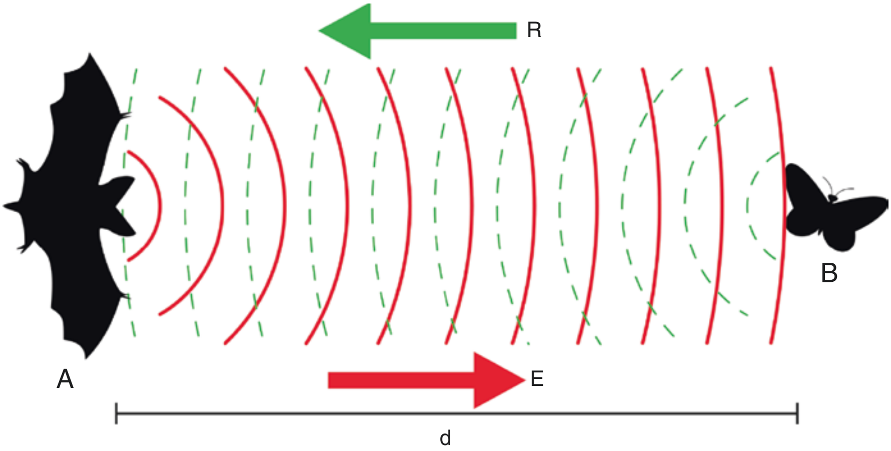

Fig. 8.1 Aircraft wing design and flight techniques inspired by birds and bats (Courtesy of. https://upload.wikimedia.org/wikipedia/commons/thumb/f/f4/Chiroptera_echolocation.svg/2000px-Chiroptera_echolocation.svg.png)

the Times of Israel describes it, “ReWalk allows independent, controlled walking similar to that of an able-bodied person, as computers and motion sensors do the ‘heavy lifting.’ The system controls movement using subtle changes in center of gravity, mimics natural gait and provides functional walking speed, enabling even paraplegics to move independently — and even to run marathons, as a paralyzed woman did 2 years ago” [1].

Some of the adaptations we can mimic include self-sharpening teeth found in rodents, copied to make better cutting tools Beavers are well known for their ability to topple large trees using nothing but their specially adapted incisor teeth and powerful lower jaw muscles. Beaver teeth never stop growing, so they do not become too worn despite years of chewing hardwoods. David Attenborough described how “the top incisors grind over the lower ones the dentine is worn away more quickly and this exposes the blade of enamel at the front keeping a sharp chisel edge” [2].

Bats are the only mammals that are capable of true flight. Bats are second only to rodents as the most diverse order of mammals and have evolved to feed on insects, fish, and fruit. Most bats communicate and navigate by echolocation, which is the process of emitting high-frequency sounds and then detecting the “echo” to identify obstacles and prey in the air. The sophistication of their unique echolocation systems surpasses current scientific understanding and has been estimated to be billions of times more efficient than any comparable system developed by humans [3] (Figs. 8.1, 8.2 and 8.3).

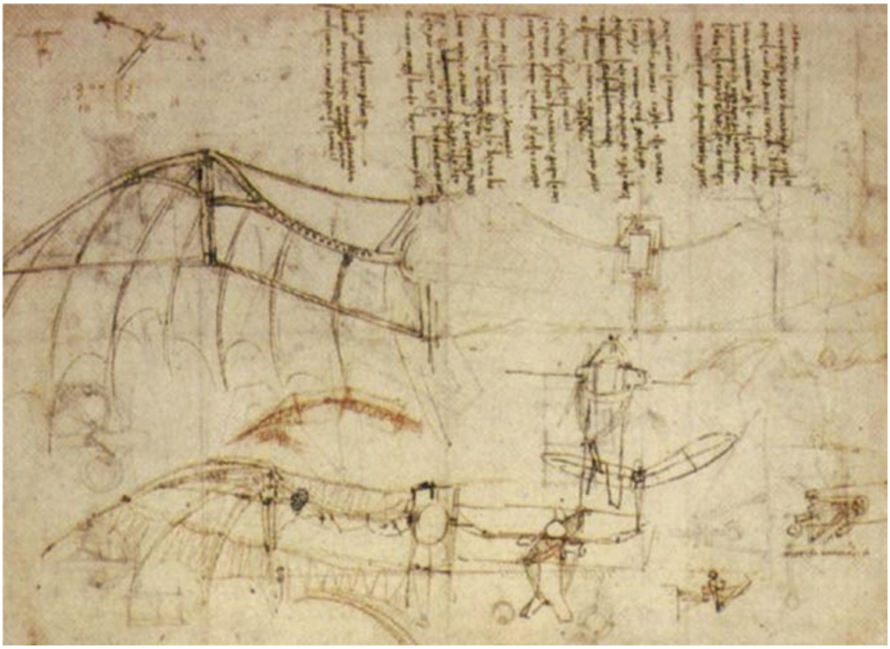

Fig. 8.2 Leonardo Da Vinci and His Flying Machine (Courtesy of https://upload.wikimedia.org/wikipedia/commons/c/c5/Leonardo_Design_for_a_Flying_Machine,_c._1488.jpg)

The ornithopter (from Greek ornithos "bird" and pteron "wing") is an aircraft that flies by flapping its wings. Designers seek to imitate the flapping-wing flight of birds, bats, and insects. Though machines may differ in form, they are usually built on the same scale as these flying creatures. The machines are of two general types: those with engines, and those powered by the muscles of the pilot [4]. A recent Livescience post stated the following: "A drone that mimics the way birds fold and flap their wings could improve the design of future unmanned autonomous vehicles, and could even help the machines withstand midair collisions." University of Florida researchers are studying the composition of horse bone, which is unusually strong and stress tolerant, to inspire a new generation of lighter, stronger aircraft material.

Velcro is perhaps the best-known biomimetric invention and was inspired by his hairy dog infested with burrs. Swiss amateur inventor Georges de Mestralt was contemplating how to eliminate the unwanted attachments on his dog's hair. As he looked at the problem closely, he decided burrs could possibly work for fastening together fabrics--the birth of Velcro [5].

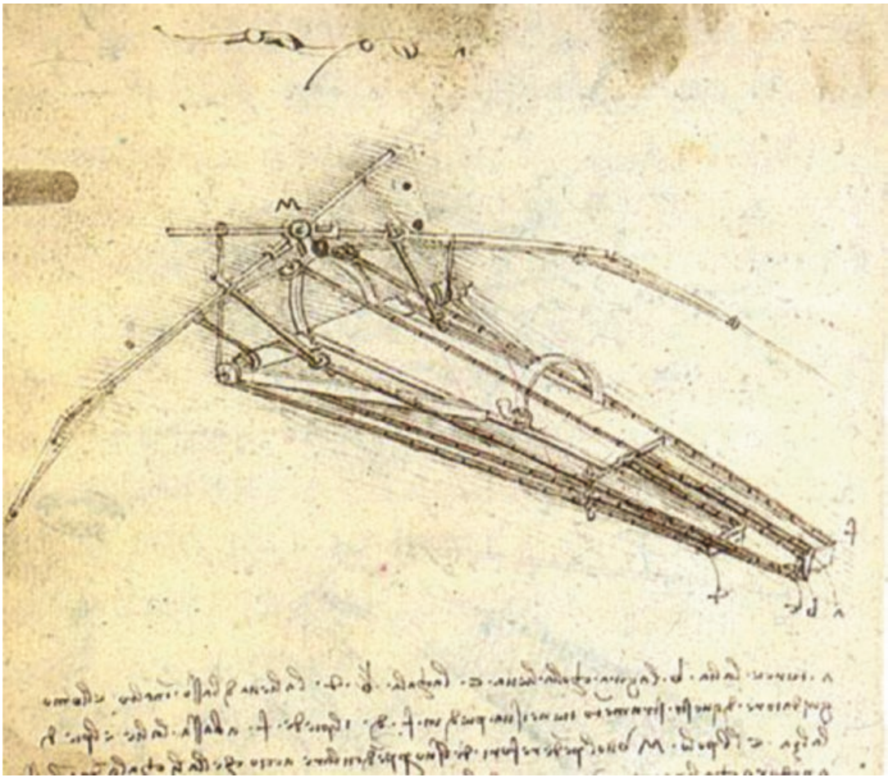

Fig. 8.3 Leonardo da Vinci – A design for a flying machine (1488) Institut de France – Paris (Courtesy of https://upload.wikimedia.org/wikipedia/commons/d/d4/Design_for_a_Flying_Machine.jpg)

Dana Ayers Baumeister, who co-founded the Montana-based Biomimcry Guild with Janine Benyus in 2000, said "If we're able to glean the wisdom of creatures that have been here far longer than us, we not only can improve upon our own innovations but learn from organisms that are living proof that we can live sustainably on the planet."

Benyus describes biomimicry as a "new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems." She writes, "Biomimicry uses an ecological standard to judge the 'rightness' of our innovations. After 3.8 billion years of evolution, nature has learned: What works. What is appropriate. What lasts. Biomimicry is a new way of viewing and valuing nature. It introduces an era based on what we can *extract* from the natural world, but on what we can *learn* from it" [6].

Benyus comments that in the 1970s we relied heavily on plants, microbes and animals for new drugs and we found 40 % of all of our prescription medicines from these sources. Included were Taxol (Pacific yew tree) for ovarian and breast cancer treatment, Vinristine (Madagascar periwinkle) used to treat Hodgkin's disease and certain types of childhood leukemia, a semi-synthetic derivative of the May apple, a common Woodland plant in the eastern United States, used to treat testicular cancer and small cell lung cancer, digitalis from the dried leaves of the purple foxglove used to treat congestive heart failure and other cardiac disorders, and Reserpine, isolated from the roots of tropical shrubs, used as a sedative and to treat high blood pressure.

By the 1970s the plants fell out of favor and soil bacteria and fungi research elicited new antibiotics. The term "rational drug design" brought synthetic chemistry and molecular biology to the forefront and pushed plants to the side. But now plants and nature have come back to center stage; although we have sophisticated techniques to design products in the lab, approximately 70 % of all new drugs introduced in the United States in the past 25 years come from nature. As Benyus writes, "Disease is having no trouble holding up its end of the arms race. Once again, hopes are being pinned on nature's biochemical registry, which is billions of years in the making" [6].

Benyus refers in her books to spiders that create web silk as strong as the Kevlar used in bulletproof vests. Engineers may use such materials for parachute lines, suspension bridge cables, artificial ligaments for medicine, and other purposes. In Montreal, the biotechnology firm Nexia is producing man-made spider filaments that may be used to make new bullet-proof vests, better surgical sutures and environmentally friendly fishing line [6].

Research is being done on the skin of cuttle fish, masters of camouflage that can change color to match their surroundings, to be imitated in designing military uniforms to provide similar camouflage. Blue mussels know how to stick around and are inspiring a new generation of waterproof adhesives including Pure Bond™, a formaldehyde-free replacement glue in particle board and other wood-based building materials [7, 8].

Climbing robots are being designed with boots and tape mimicking the feet of the gecko and their ability for adhesive reversal, and new treads on tires have been inspired by the toe pads of tree frogs. Gecko feet have incredible "dry adhesion," adhesive force enough to carry a 9 lb weight, even though the lizards weigh just a few ounces. Scientists have used the same technique that let geckos run straight up walls to create a credit card-thin "geckskin" pad that can stick a 700-lb object to a smooth wall. In addition, the geckskin can be used to create pads to put a 40″ monitor on the wall and create cheap new adhesive pads, both of which can be used and reused [9, 10].

What about plant life? One of the most important biomimicry advances has been mimicking the arrangement of leaves on a plant for better solar power collection. Phyllotaxis or phyllotaxy is the arrangement of leaves on a plant stem (from Ancient Greek phýllon “leaf” and táxis “arrangement”). Phyllotactic spirals form a distinctive class of patterns in nature.

Leonardo da Vinci was the first to suggest that the adaptive advantage of the Fibonacci pattern in the plant kingdom is to maximize number of primordia in space as to optimize their access to moisture, rainfall and sunlight. When examining a plant such as a sunflower, a repeating spiral can be represented by a fraction describing the angle of windings leaf per leaf. Alternate distichous leaves on a sunflower will have an angle of 3/8 of a full rotation. Each numerator and denominator normally consists of a Fibonacci number and the full pattern of leaves contains a Fibonacci formula [11].

Goethe – the German poet, philosopher and natural Scientist – postulated in 1830 the existence of a general ‘spiral tendency in plant vegetation’. Previously, Goethe had published in 1790 “Versuch die Metamorphose der Pflanzen zu erklären”, correctly deducing the serial homologous nature of leaf organs in plants, from cotyledons – to photosynthetic leaves – to sepals and petals of a flower, suggesting that the constituent parts of a flower are all structurally modified leaves which are functionally specialized for reproduction or protection. Goethe was cited by Darwin in *The Origin of Species* [12] (Fig. 8.4).

The prevalence of regular phyllotactic patterns in nature suggests that there must be a selective advantage of regular versus random arrangement of organs. In the case of flowers, it is conceivable that regular architecture is important for the attraction of pollinators or for an optimal packaging of seeds as in sunflower heads. For leaves, regular phyllotactic patterns can be used to avoid shading and have an optimal access to light and moisture.

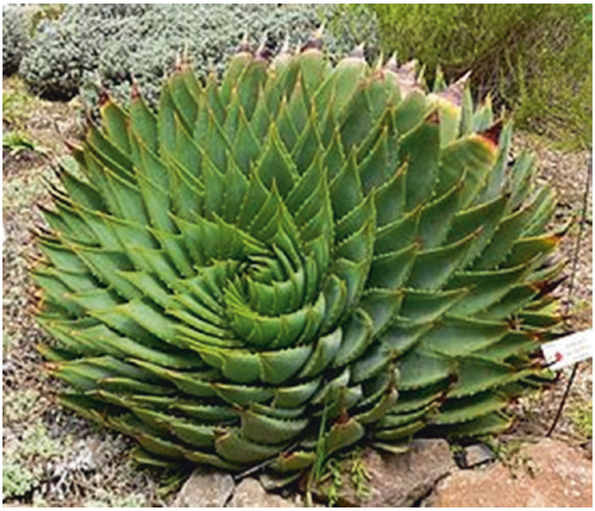

Fig. 8.4 Crisscrossing spirals of Aloe polyphylla (Courtesy of https://upload.wikimedia.org/wikipedia/commons/e/eb/Aloe_polyphylla_1.jpg)

The reoccurrence of several distinct phyllotactic patterns in nature may indicate that regularity itself also represents a selective advantage over random leaf arrangement [11].

Phyllotaxis has been used as an inspiration for a number of sculptures and architectural designs. Akio Hizume has built and exhibited several bamboo towers based on the Fibonacci sequence which exhibit phyllotaxis [13]. Saleh Masoumi has proposed a design for an apartment building where the apartment balconies project in a spiral arrangement around a central axis and each one does not shade the balcony of the apartment directly beneath [14].

A phyllotactic tower applies these patterns about the houses around the central core. The vertical and horizontal distances between the houses in phyllotactic towers can be varied through different phyllotactic patterns, based on the geographical area and climatic condition. Almost all parts of the phyllotactic tower have direct access to fresh air and sun light. The houses cast the possible least amount of shadow on each other due to the phyllotactic pattern, similar to the way of leaves in certain plants (Fig. 8.5).

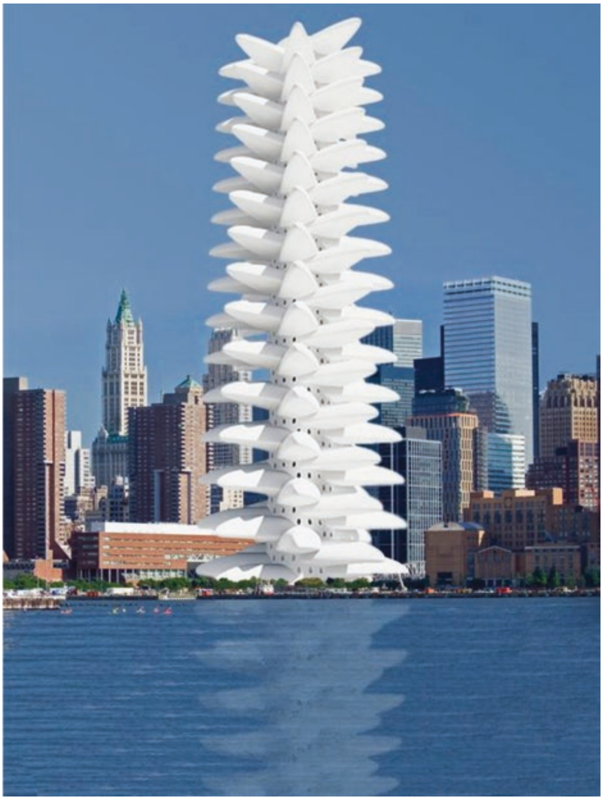

Fig. 8.5 A phyllotactic tower (Courtesy of https://commons.wikimedia.org/wiki/File:General_view_of_a_Phyllotaxy_Tower.jpg)

In summary, each ecosystem provides benefits to people, both directly and indirectly. Humans should naturally value all ecosystems and their inhabitants. In addition, each provides wonderful sources of biomimicry and bionics for the purpose of solving complex human problems. I will finish with this quote by Vaclav Havel, a writer and former President of the Czech republic: "*We must draw our standards from the natural world. We must honor with the humility of the wise the bounds of that natural world and the mystery which lies beyond them, admitting that there is something in the order of being which evidently exceeds all our competence*" [15].

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Chapter 9

The New Creationists

> The English language lacks the words to mourn an absence. For the loss of a parent, grandparent, spouse, child or friend, we have all manner of words and phrases, some helpful some not. Still we are conditioned to say something, even if it is only "I'm sorry for your loss." But for an absence, for someone who was never there at all, we are wordless to capture that particular emptiness. For those who deeply want children and are denied them, those missing babies hover like silent ephemeral shadows over their lives. Who can describe the feel of a tiny hand that is never held?. ~ Laura Bush, in Spoken From the Heart

The Book of Genesis in The Bible describes the story of creation of Adam and Eve, the first humans. But the accounts of this making of the first man varies according to different versions, and even the first part of Genesis differs from the later parts when it comes to the story of creation – for example in Genesis 1:27, God creates man and woman at the same time:

> So God created man[R] in his own image, in the image of God he created him; [R]male and female he created them.[1]

However, when we move to Genesis 2:7, it is written:

> And the Lord God formed man from the dust of the ground and [R]breathed into his [R]nostrils the breath of life, and [R]man became a living being,

Followed by 2:22, 23:

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[1] Genesis 1:1, 27 The Open Bible, The New King James Version. Thomas Nelson Publishers, New York. 1982.

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R.A. Norman, S.P. Paul, *The Last Natural Man*,
DOI 10.1007/978-3-319-42217-6_9

> So the LORD God caused a [R]deep sleep to fall on Adam, and he slept; then He took one of his ribs and closed up the flesh in its place. Then the rib which the LORD God had taken from the man, He [T]made into a woman and brought her to the man.[1]

The Tanakh or the Hebrew Bible has other variations. In fact, Midrash Rabbah, or Rabbinic writings that interpret the Tanakh more liberally, even suggest that "male and female, He created them" may indicate that God may have created Adam as a hermaphrodite.

The concept of the first human being both male and female is not unlike other religious texts. For example, the Hindu God, Shiva, in his incarnation as 'Ardhanari' is a hermaphrodite form of Shiva fused with his wife Parvati (or Sati). Most Hindu writings consider Shiva and Sati part of the same being. However, the story in the *Kurma Purana* goes that when an angry creator Brahma, furious with Shiva for refusing to reproduce and populate the Earth, created a hermaphrodite being – with a masculine half (Rudra), and a feminine half (Uma). Uma was then given to Brahma's own son Dakshi, to be born as his daughter, whom Shiva was destined to wed. Once again, different versions of creation abound, but the story centers around a creator fusing together male and female forms.

But religious myths get lost in the forests of science, and searching such realms may lead to dangerously good ideas. Scientists are people that believe that all things are possible, and that dreams and myths of our forebears may indeed come alive as technical realities in our lifetimes. The scientific book of Genesis was a fairly long time coming, but in a little lab in Cambridgeshire, England, scientists finally became creationists – when on July 25th 1978, Louise Brown became the world's first 'test-tube baby' (never mind that these embryos were conceived in petri-dishes rather than test-tubes) marking a new frontier for human fertility treatment. For several years, gynecologist Patrick Steptoe and scientist, Robert Edwards had been experimenting with fertilizing human eggs in a laboratory – scientists had already been fertilizing animal eggs outside the body and the duo decided to create human embryos in the same way. Eggs were taken from the ovaries, fertilized in a small dish and returned to the womb after they had been fertilized. Given the NHS would not fund their idea, Steptoe and Edwards set up their private clinic in Bourn, just outside Cambridge. The idea was controversial and many of the women volunteers were forced to be very secretive about their "treatment", which was in those days, was very rigid. Women collected urine samples every few hours so that doctors could monitor hormones to detect the "ovulation surge", eggs were collected exactly 26 hours after this hormone surge, women had to crouch in a 'fetal position' for an hour after the embryo had been transferred back into their wombs – all very different from today, where IVF babies are common and there are over 5 million IVF babies worldwide. Yet, in 1978, not everyone received the idea of IVF with enthusiasm. Louise Brown recalls how her family was bombarded with hate mail that sometimes arrived in blood-splattered envelopes.

Within this field of in-vitro fertilization, there have been many advances – freezing techniques have improved, allowing for storage of spare embryos, sperm can be directly injected into eggs (a technique called ICSI – intra-cytoplasmic sperm injection) which means infertile men can also father a child.

But there have been several advances in genetics since 1978. The human genome has now been mapped, giving us insight into many diseases, and indeed the genetic story of Adam and Eve is a bit different from the version in Genesis. Here's the scientific truth: Adam and Eve did exist, albeit eons apart. We know women have XX chromosomes and males have XY chromosomes. Men therefore pass on Y-chromosomes to their sons, and therefore it is highly probable mathematically that at some point in the past, all men except one possessed Y-chromosomes that by now are extinct – our scientific Adam; Women, in contrast, pass on mitochondrial DNA (mtDNA) to both sons and daughters – we know this from the study of mitochondria-linked diseases. Therefore as we trace back our mitochondrial lineages, scientific theory predicts that all mitochondrial genomes today should be traceable to a single woman, our scientific Eve (perhaps Eve's surname should be mitochondria).

Nearly a decade after the first test-tube baby was born, Rebecca Cann and colleagues from Berkeley studied the mitochondrial DNA of 147 individuals, and concluded that our Eve probably lived in Africa around 200,000 years ago. But more recently, scientists came up with a more accurate figure – in a larger study, an analysis of the same men's mtDNA sequences suggested that Eve actually lived between 99,000 and 148,000 years ago, whereas Adam, the original source of the portion of the Y chromosome that passes from father to son, lived around 100,000 years ago.

When it comes to reproductive technology, the next name to be immortalized after Louise Brown was Dolly The Sheep, the world's first cloned mammal. Like Louise, Dolly started her life in a 'test-tube' – via a process called 'Nuclear Transfer' wherein a genetically identical animal is created by transferring the nucleus of a body cell into an egg from which the nucleus has been removed – in Dolly's case the cell used was from a mammary gland (hence the name, Dolly, after Dolly Parton's famous bosom). But cloning is not as simple as it seems in theory. When Dolly was a year old, her telomeres (located at the ends of chromosomes and associated with longevity), were found to be shorter than expected for her age. While Dolly was a vigorous animal, she died in 2003. Her body has been stuffed and on display at the Museum of Scotland. However, the possibility of cloning has excited a lot of interest – as the University of Edinburgh's Roslin Institute (that created Dolly) notes, 'one Australian project aims to resurrect the 'Tasmanian tiger' by cloning from a specimen that had been preserved in a bottle of alcohol for 153 years and another research group announced plans to clone a mammoth from 20,000 year old tissue found in the Siberian permafrost.'[2] Human cloning is considered unethical and also very difficult to achieve – even in animals only about 1 % of attempts at cloning succeed. Robert Lanza, a scientist at Advanced Cell Technologies, someone who works on cellular therapies for diseases and has successfully cloned animals has been quoted as saying this about human cloning[3]: "It's like sending your baby up in a rocket knowing there's a 50–50 chance it's going to blow up. It's grossly unethical."

However, with the advent of IVF, society entered a new phase of reproduction from a technical point of view, and also society's concept of family structures began changing – adoption laws have changed, homosexual couples are allowed to adopt children etc.

Bruce Lahn is a Professor of Genetics at the University of Chicago and an investigator at the Howard Hughes Medical Institute. In an interview in Gene Expression, he said[4]:

> I think we as a species now stand at a watershed moment in the history of life. For billions of years, evolution of life forms has been governed by the Darwinian process of random mutations followed by selection. Now, we are about to revise that principle dramatically by genetic engineering. Instead of starting with random mutations, of which only very few are advantageous, we can now prospectively change our genome (and the genomes of other species) in ways we intend. In a sense, genetic engineering will make Lamarckian evolution a reality … likely speed up evolution enormously, and create life forms, including those derived from our own species, in ways that the Darwinian process can never hope to accomplish.

Professor Lahn was referring to Jean-Baptiste Lamarck's theory of 'soft inheritance' i.e. the concept that an individual, during his lifetime and lifestyle would have certain 'acquired characteristics' that could also be passed onto offspring, as opposed to one's genetic destiny being pre-determined at birth. It is time to look at what the future of reproduction will look like and it is time to look at where human reproduction is headed. To be a parent in the future will have a different meaning altogether. The new role for parents seems to be not as guides, but as genetic messengers.

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The well-worn adage may say "two is company, three is a crowd" but when it comes to genetic technologies, the dictum may well be 'the more, the merrier.'

About a year ago, the FDA discussed the ethics of allowing three-parent-embryos. The technique could prevent mitochondrial disease – in this technique scientists take DNA from the nucleus of an egg from a woman afflicted with mitochondrial disease, and place it into the egg of a second woman, who has healthy mitochondria. This hybridized egg is then fertilized with a man's sperm. While controversial, this technique eliminates mitochondrial diseases which are otherwise impossible to prevent.

Mitochondrial diseases are those caused by the dysfunction of these tiny powerhouses of the cell. Mitochondria are found in all cells except red blood cells and generate ATP, the energy currency used by most cells. Mitochondrial disorders lead to conditions like ptosis (eyelid lag), proximal myopathy (muscle weakness), cardiomyopathy and even conditions like diabetes. Muscle biopsies are usually done to diagnose these conditions and indeed the study into mitochondrial diseases was what led researchers to find Eve.

Dr Shoukhrat Mitalipov is a senior scientist at the Oregon Health and Science University in Portland and a pioneer of three-person embryo transfers. Buoyed by the approval of the UK parliament of three-person embryos to prevent mitochondrial disease, Dr Mitalipov is seeking FDA approval to use this method to help infertile couples. Mitochondrial diseases are relatively rare, but infertility is not. Given in modern societies, women are putting off having babies until older, Dr Mitalipov feels that using three-person embryos would allow older women to have children. However, using this for infertility treatment is controversial.

Jarod Kintz, in 'This Book is Not FOR SALE' wrote, "I'm an only child, and therefore I gave birth to my parents, because if it weren't for me, they wouldn't even be parents" – but even he may concede that having three parents may be over the top, even if it appears to be one of the ways of the future. Think about the poor child having to fill our forms at schools listing the names of parents …

In recent years, surrogacy or "wombs for rent" have become increasingly common. In many third-world countries, poverty-stricken women have resorted to such business arrangements purely as an income source.

In 2013, there was a newspaper report[5] about Michael, a British doctor and his Russian wife, Veronica, who had traveled to Gujarat, India, to Dr. Nanya Patel's rural clinic to have two of their embryos carried by a surrogate mother, a complete stranger. The irony wasn't lost on the doctor who was quoted as saying, "As a physician, I find it somewhat ironic to see poor individuals who are pregnant and choose to terminate their baby… and individuals who wish deeply to be pregnant but are unable to." Dr. Nanya Patel's clinic, that was later featured in a documentary is part of the corporate-style commercialization that surrounds all fertility treatment, not just surrogacy in the third-world – in the UK, the IVF industry is estimated to be worth around 600 million pounds; in India, Dr. Patel pays her surrogates US$8,000, and pockets $28,000 for her efforts. While critics are horrified at this 'baby-factory', where as many as 80 surrogate women live in over-crowded dorms, there is no shortage of couples from the West flocking to Gujarat.

But not all cases go to plan. Sometimes when complications or birth defects arise, the parents are not as keen on a defective child. Recently it was reported[6] that a surrogate mother wanted to carry triplets, in spite of the biological parents pressuring her to terminate the pregnancy. Brittanyrose Torres told the New York Post that the parents wanted her to terminate one of the three fetuses, but she did not want to abort unless it was a life-and-death situation.

In the earlier case of Michael and Veronica, Veronica was born with only one fallopian tube and ovary, making it difficult for her to conceive. In other cases, women are born without a womb and have no possibility of carrying their own child. Until recently, that is. One of the other medical advances has been in the field of 'womb transplants.' In Sweden, Malin Stenberg and her partner, Claes Nilsson refused to accept a childless life. Malin was born without a uterus. A 61-year-old family friend Ewa Rosen decided to donate her womb to Ms Stenberg as she was well past the childbearing age herself. Richard Smith, head of the charity Womb Transplant UK, is following the Swedish example. An estimated 15,000 women are born without a womb in the UK. But such womb transplants are not easy, nor for the faint-hearted – as with any transplant surgery, immunosuppressant medications are required and once pregnancy is established and the child born by Caesarian section, the uterus is removed to avoid any further complications of a suppressed immune system.

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[5] Deni Kirkova. Wombs for rent in India: Inside the 'house of surrogates' where poverty-stricken women carry babies for wealthy foreigners. Mail Online. 30 Sept, 2013. http://www.dailymail.co.uk/femail/article-2438835/Wombs-rent-India-Inside-house-surrogates-poverty-stricken-women-carry-babies-wealthy-foreigners.html accessed Feb 1 2016.

[6] CBS News, Dec 16, 2015. Surrogate mom carrying triplets fights biological parents on abortion. http://www.cbsnews.com/news/surrogate-mom-with-triplets-fights-biological-parents-on-abortion/accessed Feb 1, 2016.

The ultimate reason of reproduction may be existential for other species, but for humans it is not about the constant parental anxiety, or the "terrible twos", but the pleasure one receives from having a little version of oneself – visually and existentially. But as we push the boundaries with three-parent families, and transplanted uteri, we have to ask, 'Are these crowd-sourced beings children, creative adventures or clones?'

Until recently, embryos were the only source of stem cells for reproductive research. However, given my main medical work is in the field of skin cancer, I have long been interested in the use of skin cells as donors. The average human loses 200 g of skin cells daily – these cells are constantly producing more cells that migrate outwards to the top of the epidermal layer, lose their nuclei, dry up and disintegrate into dust. Early in my surgical career, I worked in the field of burns and tissue culture. We were using embryonic stem cells to produce skin cells, but could skin cells in turn produce stem cells? This topsy-turvy idea indeed came to fruition when Professor Shinya Yamanaka published his breakthrough paper on "direct reprogramming" i.e. creating equivalents of cloned embryonic stem cells from adult skin cells, thereby doing away with the need for women's eggs or embryos. This Japanese team used recombinant technology—they used a retrovirus as a mule, carrying four genes that they had previously used to 'reprogram' mouse cells. The human skin cells, once reprogrammed, began to produce stem cells. And these cells are pluripotent i.e. capable of developing into various different tissue types. Dr. Mehmet Oz, on an Oprah Winfrey Show that discussed the benefits of using skin stem cells in research into Parkinson's disease, said[7]:

> I think, Oprah, the stem cell debate is dead, and I'll tell you why … The problem with embryonic stem cells is that they come from embryos, like all of us were made from embryos … In the last year we've made ten years' advancement … and here's what the deal is: I can take a little bit of your skin, take those cells, and get them to go back in time so they're like they were when you were first made.

Until now, stem cells were used to create specific tissues of bodily organs. However, in the realm of reproductive science, this opens new possibilities for the future –can stem cells make new sperm or eggs?

On Christmas Eve in the year 2014, researchers successfully created human sperm and egg precursor cells in a dish, starting with a person's skin cells. In 2012, stem-cell biologist Mitinori Saitou of Kyoto University in Japan had actually attempted this same technique and had succeeded, however only in mice. However, when Saitou attempted to replicate the method on human cells, the experiment failed – as unlike mice cells, that are ‘naïve’ (can be coaxed in any direction), human cells are smart (and are already ‘primed’ to produce specific tissues). However, when researchers in Israel and Britain repeated Saitou’s experiment, they managed to ‘tweak’ human cells to behave more like mice cells, and they ended up in creating sperm and egg cells in the lab.

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[7] Dr Mehmet Oz on the Oprah Winfrey Show, featuring Dr Oz and Michael J. Fox, 31 March 2009.

This business of creating eggs from skin cells opens a scientific can of worms – for example one could produce sperm and egg from a single man’s skin cells (giving a whole new meaning to children getting under a parent’s skin) or two men could produce an embryo that could end up in a womb for rent. However, in the age of equal rights, there are some major technical hurdles for two women to manage to procreate without a man – enabling two women to have biological children together is not technically feasible because only men have the Y chromosome, needed to produce sperm cells.

The key breakthrough that allowed scientists to produce embryos from skin cells was the ability to reprogram skin cells – scientists now know that a gene called SOX17 is critical in the process of reprogramming human cells. Jacob Hanna, the leading scientist of the Israeli arm of the study was quoted as saying,[8] “It has already caused interest from gay groups because of the possibility of making egg and sperm cells from parents of the same sex.” He feels that by 2017, his team will be ready to create babies using this technique.

Modern man migrated out of Africa a mere 100,000 years ago. At that time humans had a small footprint – whatever humans did, it did not matter to the Earth – and had minimal bearing on the environment or other species. But, in 100,000 years man has populated the Earth to every corner and damaged the environment – with a footprint so large that it threatens to trample over many other life forms, plant or animal. But one could argue that one of the reasons for this over-population is a human being’s fundamental desire to create new beings in one’s own image. Playing God.

In the old world, there were many conflicts, but cities were arranged in hierarchical orders – housing was often communal, and architecture was consistent. When one travels to old Europe from Australia or America, one is struck by the sameness of architecture – less individual flair in design was permitted in the old days to maintain certain decorum. We now live in an age of individuality, where an individual or a corporation's success, rightly or wrongly, seems to have gained ascendency over society's needs. Just as housing designs are more individualistic, so is the future of human reproduction – welcome to the new world of designer babies, the final frontier of fertility advance.

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[8] Ben Spencer. Daily Mail. 23 Feb 2015. “Babies with no mother: Scientists say they can make human egg from skin of two men in new hope for infertile couples. But breakthrough sparks new fears over ‘designer’ children.” Mail Online. http://www.dailymail.co.uk/news/article-2964586/Scientists-say-make-human-egg-skin-two-men.html accessed 1 Feb 2016.

When I ask people about what they would choose as a genetic trait if they had the choice, they generally list beauty, intelligence or sporting prowess. In the age of genetics, where the entire human genome has been mapped, can we manipulate genes to achieve what we desire?

Are humans are we meant to have different abilities – to run, to swim, to jump and procreate? As this technology could in the future lead to attempts to engineer athletic prowess, is this kind of IVF therapeutic treatment or bioengineering?

In October, researchers published a study in the journal, *Current Biology,* where they studied the genetic traits for beauty in identical twins. It transpires that our perceptions of beauty are mostly the result of personal experiences that are unique to each individual. Even identical twins in this study could not agree on who was beautiful (or not). Therefore beauty is indeed in the eyes of the beholder. However, given Western media currently shapes our perception of good looks, parents of the future may choose to design a baby with specific eye or hair color – for example, we already know that a non-working OCA2 gene is one of the steps needed for blue eyes –after all it has been proven scientifically that all blue-eyed people have one common ancestor, and this person appeared as recently as 6,000–10,000 years ago – therefore it is possible to try and create a child with blue eyes for instance; or a non-working KITLG gene, which causes skin lightening and also causes hair to change from brown to blonde; two copies of a defective MC1R gene and you end up with red hair etc.

Scientists have been on the search for the intelligence gene – but this has proven elusive, as there are many aspects to intelligence – language skills, memory and analytical ability. However, very recently, scientists from Imperial College London have identified two clusters of genes that they believe are linked to human intelligence. Named M1 and M3, they may sound more like vehicle carriageways, but these networks appear to relate to cognitive functions – roadmaps to do with memory, attention, processing speed and reasoning. Dr. Michael Johnson, the lead author says,[9] "What's exciting about this is that the genes we have found are likely to share a common regulation, which means that potentially we can manipulate a whole set of genes whose activity is linked to human intelligence. Our research suggests that it might be possible to work with these genes to modify intelligence, but that is only a theoretical possibility at the moment – we have just taken a first step along that road." As a doctor, I am excited that this has the potential for treatment and prevention of conditions like Alzheimer's disease and epilepsy. However, in the future, clients with financial resources could ensure these genes are optimized in their offspring at the embryonic stage.

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[9] Kate Wighton. Imperial College London. Intelligence 'networks' discovered in brain for the first time. http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_22-12-2015-10-13-44 accessed Feb 1, 2016.

Actually, not that long ago, I remember reading a Scientific American report[10] about a company that was offering genetic testing for athletic prowess – for $149, the company's president claimed that he could test for variants of the gene ACTN3, which in champion athletes is associated with the presence of the muscle protein alpha-actinin-3 – a protein that helps muscles contract at high speeds. The theory was that a child with two copies of the R variant would make more alpha-actinin-3, and therefore parents could steer the kid towards sports like football or sprinting that could lead to major financial rewards. But over the decade this test has proved more fantasy than reality and I am not sure the company even exists today, even if many others have sprung up.

An eminent panel of international scientific experts recently concluded that while we can map the whole human genome, science has not made much progress in finding a gene that determines athletic prowess. Indeed over the past 10–15 years, many groups have looked for a genetic variant present in elite athletes (and not in others), but have found nothing. Thankfully, for now, hard work, 10,000 hours of sports training and determination will have to do.

Nevertheless, the fact that the search is on to identify genes for beauty, intelligence and sporting prowess means that in the future, such tests may be possible. As a doctor who initially entered plastic surgical training, I realized that most people who presented for cosmetic surgery really needed their head treated; that made me steer clear of cosmetic surgery, and into reconstructive surgery, and I finally ended up in skin cancer work. Sadly, with the increasing commercialization of medicine -- even today, doctors will perform unregulated or "enhancing" procedures if offered enough cash. The future suggests that in an increasingly competitive world, unless strict regulations are in place, eugenics is inevitable, as parents seek to give their children an edge. If we think that the difference between the haves and the have-nots is largely financial today, in the future it may be genetic.

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[10] Jordan Lite. Can genes predict athletic performance? Scientific American. Dec 1, 2008.

Some genetic scientists will be the neo-Nazis of medicine in the future. And, that's a scary thought.

As a physician, when I think of genetic eugenics shaping babies of the future, I feel a confused admiration for technical skills and a shame that doctors could in the future lack an understanding of what it takes to be human. Last week I had a patient tell me someone they knew was about to fly to Thailand because a clinic had guaranteed her a boy child and such sex-selection was not legal Down Under.

Children need to be free – from binds of homelands, full of individual choice and with the ability to live freely. However, as the search for genetic traits moves forward with relentless corporate zeal, genetic testing and specific trait-selection will be available in the future. How we deal with this shall determine if the world remains our home or a haunted house.

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Chapter 10

The Replaceable You

> Human beings have become useful to each other in ways never before possible.
> Emanuel Thorne, Aspen Institute

Figuring out what you want to do to improve yourself presents a bewildering variety of choices. You can read a self-help book such as “A Hundred Ways to Improve Yourself in Under Ten Minutes for Less Than Five Dollars”, travel to Upper Lower Mongolia for an Environmental Encounter, or spend endless hours doing cardio boxing with a kangaroo. But maybe the problem is something else, something that requires a more permanent physical fix. And you turn on your computer and read about the Replaceable You Menu. Each item sounds great, and you can’t decide what to order. Each one feels like an adventure, and you want to learn more. Some you want to pursue further. Others are appetizers, items you can sample before diving in for more.

The Replaceable You Menu is a virtual Pu-Pu platter of tasty morsels listed in a prominent web site, with some possibility for anyone. The old favorites are on the menu, such as hip or knee replacement. Many of the items may be either new or variations of old standards that are filled with exciting ways to put more zip in your drive or eliminate the catch in your giddy-up. Tasty! While you browse, you will move on to Nouvelle cuisine, and you can sample delicacies such as knee shaving, tricks on tattoo removal, and new focus in laser eye surgery. Spicier dishes can be had for a price, including sex change surgery or breast augmentation. As for dessert, you have a plethora of after dinner delights. When you decide, you click on the menu, input your genetic and other personal data, and choose the procedure that offers the closest location, best price, and other qualifying criteria. Click and make your rendezvous with a new you.

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Does this seem like a dream scenario? Many of us feel like we are swimming upstream genetically, grasping at buoys of hope in the middle of turbulent seas. I believe part of the task of being fully human is to help one another achieve our maximum potential, which often involves improving on what the good Lord and Mother Nature has given us. The Replaceable You is already happening and continues to snowball. The idea of replacement offers incredible insight into improvements available now to help alleviate struggles and improve cosmetically. As new procedures roll out, you can glimpse the future of what will be available right around the corner.

The Replaceable You Menu is not a "cookbook," a body replacement manual, or the equivalent of an auto mechanic guide set atop the motor for reference during repairs. The world of transplants, for example, is complicated, involving the most advanced techniques of surgery, immunology, nursing, psychiatry, cardiology, infectious disease, dermatology, nephrology, and other disciplines. The primary goal of The Replaceable You Menu is to simplify the complex world of transplants, replacements, cosmetics, and corrective surgery into an accessible, organized, and intriguing guide for all of its readers.

Sections on hair transplantation, breast augmentation and reduction, tattoo removal (are you changing mates?), penile implants, sex change operations, corrective rhinoplasty, and other topics are included in the cosmetics/corrections sections. The procedures are listed from the top down--from hair to feet--to make it easier to find. Sidebars include stimulating vignettes such as Voice of the Patient and Important Tips and specific ones such as Religious Views on Transplants.

A general introduction covers the reason for the menu, followed by sections on cosmetics/corrective surgery and transplantation/replacements, and donor networks and resources with phone numbers and addresses. What procedures are available and what risks are involved? The general public and health educators, including physicians, nurses, and school teachers need this book for reference.

In each day's newspaper, articles appear detailing our ability to replace and improve ourselves. Features on organ transplantation, cloning, joint replacements, and cosmetic procedures fill the news and airwaves. And the number of procedures keeps growing.

Many groups have blossomed to help save lives. The mission of the American Transplant Foundation works to reduce the growing list of women, men, and children who are waiting for a transplant by maximizing living organ donation. Over 617,000 transplants have occurred in the U.S. since 1988. The cornea is the most commonly transplanted tissue; more than 40,000 corneal transplants take place each year in the United States.

More than 123,000 people in the United States are currently on the waiting list for a lifesaving organ transplant and another name is added to the national transplant waiting list every 12 min. On average, 21 people die every day from the lack of available organs for transplant and 7 % of people on the waiting list—more than 6,500 each year—die before they are able to receive a transplant. Here is an amazing fact as mentioned on the American Transplant Foundation website, namely that "one deceased donor can save up to eight lives through organ donation and can save and enhance more than 100 lives through the lifesaving and healing gift of tissue donation." Organs that can be donated after death are the heart, liver, kidneys, lungs, pancreas and small intestines. Tissues include corneas, skin, veins, heart valves, tendons, ligaments and bones.

A healthy person can become a "living donor" by donating a kidney, a part of the liver, lung, intestine, blood or bone marrow. More than 6,000 living donations occur each year and one in four donors is not biologically related to the recipient.

The buying and selling of human organs is not allowed for transplants in America, but it is allowed for research purposes. In most countries, it is illegal to buy and sell human organs for transplants, but international black markets for organs are growing in response to the increased demand around the world, often called "Transplant Tourism."

According to statistics from the American Society of Plastic Surgeons (ASPS), 14.6 million cosmetic plastic surgery procedures, including both minimally-invasive and surgical, were performed in the United States in 2012. The top five minimally-invasive procedures were Botulinum toxin type A, soft tissue fillers, chemical peel, laser hair removal, and microdermabrasion. The top five cosmetic surgical procedures were: breast augmentation, nose reshaping, eyelid surgery, liposuction, and facelift. In addition, 5.6 million reconstructive plastic surgery procedures were performed that year. The top five reconstructive procedures were: tumor removal, laceration repair, maxillofacial surgery, scar revision, and hand surgery. Reconstructive breast reduction accounted for more than 68,000 procedures.

Beyond transplants and cosmetics, more than 300,000 people yearly receive bone, tendon, ligament, and connective-tissue implants. Hundreds of thousands of replacement procedures occur annually. We clearly need to keep in mind what procedures are life-saving (transplants) vs. cosmetic (Botox) and not conflate all modifications under one umbrella.

What do we do as the Last Natural Man slowly fades away? We certainly still try to be "natural" today, as evidenced by The Paleo Diet and other attempts to tap our native reservoirs and improve ourselves. But is this a pipe dream, a kumbaya nostalgia for some atavistic echo of our past?

Isn't it easier to just replace broken parts as you go, eat genetically engineered food, and try to maintain as much brain health as possible? How much time will go by before almost every human being on the planet will be at least partially bionic? Most people will soon be getting genetic tests at birth to establish a personal genome and determine the most effective use of future individual therapy, including which parts might be faulty and need replacing. What is the best road to travel?

New insights have been offered by writers such as the historian Yuval Noah Harari (mentioned earlier) while answering the biggest question in his book *Sapiens: A Brief History of Humankind*: How did Homo sapiens evolve from an unexceptional savannah-dwelling primate to become the dominant force on the planet, emerging as the lone survivor out of six distinct, competing hominid species? Harari describes human development through a framework of three not-necessarily-orthodox "Revolutions": the Cognitive, the Agricultural, and the Scientific. Harari asks, "Why not go back to God's drawing board and design a better Sapiens?" If, as Harari writes, the abilities, needs and desires of Homo sapiens have a genetic basis, can genetic engineering and other forms of biological engineering "enable us to make far-reaching alterations not only to our physiology, immune system and life expectancy, but also to our intellectual and emotional capacities."

Harari writes, "The Cognitive Revolution that turned Homo sapiens from an insignificant ape into the master of the world did not require any noticeable change in physiology or even in the size and external shape of the Sapiens brain. It apparently involved no more than a few small changes to internal brain structure. Perhaps another small change would be enough to ignite a Second Cognitive Revolution, create a completely new type of consciousness, and transform Homo sapiens into something altogether different." Harari notes that we don't have the acumen to achieve this yet, but "there seems to be no insurmountable technical barrier preventing us from producing superhumans." Although the main obstacles are the "ethical and political objections that have slowed down research on humans," he notes that "no matter how convincing the ethical arguments may be, it is hard to see how they can hold back the next step for long, especially if what is at stake is the possibility of prolonging human life indefinitely, conquering incurable diseases, and upgrading our cognitive and emotional abilities."

I truly love the acts of reading and learning and writing. However, I would love to be able to input a book with as many words and ideas as the one you are now reading into my consciousness without all the required hours of reading and processing necessary for the cerebral download. And what about the quality and amount of the material digested? How much can be tapped again once processed? When I saw the scene from the Matrix when Keanu Reeves was getting a massive information infusion via a cable at the base of his neck, allowing him instant access to the world's knowledge, I said "Sign Me Up" out loud. If it could really happen, perhaps with each new idea entered into the mind it would incrementally and exponentially increase a person's awareness and understanding of the world. In simple terms, we see what we know and we will begin to see and know more with added information. Of course, one has the risk of not being able to fully use the knowledge or not be able to filter out chaos and retain pertinent data so it does not hang like rusty tools in the mind's garage. Wisdom is not just the accumulation of data but hopefully it implies the best way to use the new mental acquisitions for the maximum benefit. Of course, this desire to rapidly improve is not a new idea, and many of us hunger for ways to more easily carefully accumulate all the important information swirling around us.

Here is where I believe Harari shines most brightly in his observation. He writes, "Yet of all the projects currently under development, the most revolutionary is the attempt to devise a direct two-way braincomputer interface that will allow computers to read the electrical signals of a human brain, simultaneously transmitting signals that the brain can read in rum. What if such interfaces are used to directly link a brain to the Internet, or to directly link several brains to each other, thereby creating a sort of Inter-brain-net? What might happen to human memory, human consciousness and human identity if the brain has direct access to a collective memory bank?" Could we choose to have collective acquired consciousness that would parallel the collective unconscious purported by Jung? And who would decide what is programmed? If Jung's collective unconscious refers to structures of the unconscious mind shared among beings of the same species, will a varied neural input prompt us to consider a separation of species based on different computer and information formatting?

Back to *The Last Natural Man*. As Harari writes, "Tinkering with our genes won't necessarily kill us. But we might fiddle with *Homo sapiens* to such an extent that we would no longer be *Homo sapiens*." How will we attempt to survive the medical and social problems of our future using our natural inventiveness?

Chapter 11

Sensing the Future

Vision

> All we have to believe is our senses: the tools we use to perceive the world, our sight, our touch, our memory. If they lie to us, then nothing can be trusted. ~ Neil Gaiman, *American Gods*

In ancient times, people born blind were considered cursed. It is obvious shortsightedness would have been a major disadvantage while avoiding predators and danger. Eyes and vision were considered the greatest of senses. In the Bible (Mathew 6:22) there is the verse: "The eye is the lamp of the body; so then if your eye is clear, your whole body will be full of light."

With the passage of time, the mechanisms of eyesight began to be studied, and concepts such as color-blindness began to be studied. About 200 years ago, John Dalton, the English chemist, pioneered research into his own color-blindness – and spawned a new scientific term for this affliction named after him: Daltonism – and brought style and substance to the scientific debate regarding the origins of this mysterious malady.

Dalton suspected that the vitreous humor of his eye, the gel-like substance that fills the space between the lens of the eye and the retina, had a blue tint – and this blueness resulted in his eyes selectively absorbing colors in the red-green spectrum. So confident was he, that he bequeathed his eyes for research to prove his hypothesis. However, upon his death, his eyes were examined and no such blue pigment was found. Therefore Joseph Ransome, the physician that examined Dalton's eyes posthumously, concluded that the brilliant Dalton perhaps had "deficient brain development".

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Today we know that color-blindness is genetic. Indeed all 12 primate species (including man) have vision that is trichromatic—depending on three different types of cone pigments handling different wavelengths: short-wavelength (SW) for blue pigment, the middle-wavelength (MW) for green pigment, and the long-wavelength (LW) for red pigment. In Dalton's case, he lacked the MW wavelength, that we now know is encoded by genes at the distal end of the q arm of the X chromosome.

Humans and primates are trichromats i.e. use only the three-color senses described above, yet can sense millions of colors. In contrast, insects such as bees are tetrachromats (4-colors) and butterflies are pentachromats (5-colors), putting paid to Darwin's theory – at least when it comes to eyesight. As the genetics of eyesight and color vision advances, we now know that there are pentachromats amongst humans – a few genetic aliens that possess superhuman color vision, yet the significance of this is still unknown.

Speaking of superhuman eyesight, even contact lenses would have seemed unnatural for early humans. But there have lived men with a remarkable vision of the future, not just of the ocular kind. Men like Leonardo Da Vinci. History suggests that Da Vinci had thought about neutralizing the irregular surface of an eye by means of a regular surface full of water, thus substituting the cornea with a new refraction surface.[1] Later, some people attempted to place glass prostheses, called "contact crystals" over the cornea in an attempt to correct any irregularities or treat diseases such as keratoconus using pressure (keratoconus is a disease where the cornea appears cone shaped). The first person to try and use a lens in contact with the human cornea to correct shortsightedness was Müller, who attempted this in 1888.

Müller was very shortsighted and needed thick glasses to the order of 14 diopters. Tired of wearing spectacles, he placed a glass "contact lens" on his cornea and found that he was able to tolerate the sensation for half-an-hour. However, during this era, scientists we not aware that the cornea needed oxygen, and therefore lenses or materials were not oxygen-permeable.

Edward Goodlaw, one of the pioneers of the contact lens industry was the first to recognize that the cornea may indeed require oxygen. He was working for a laboratory that was making contact lenses and molds were taken of people's eyes. Reminiscing about that experience, he wrote,[2]

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[1] A.V Sánchez Ferreiro. Evolution and history of contact lenses. Archivos de la Sociedad Española de Oftalmología (English ed.) Volume 87, Issue 8, August 2012, Pages 265.

[2] Edward Goodlaw. A personal perspective on the history of contact lenses. International Contact Lens Clinic. Volume 27, Issue 4, July–August 2000, Pages 139–145.

> After about 15 minutes patients always complained of a 'burning' or 'hot' sensation. This was exactly the same report when a solution that was too acidic was used. Then, always after about 3 hours wear, our patients complained of seeing haze and 'rainbows' around lights, which we called 'Sattler's Veil.' Troubled by these reports, I went to the Los Angeles downtown public library to try to understand the principles of osmosis better. During my reading, I learned that the epithelium of the cornea was a highly metabolic tissue. If metabolism was occurring, I reasoned, oxygen had to be consumed and carbon dioxide given off.

Finally had come the realization that the eyes breathed. Goodlaw's research led to the development of oxygen or gas-permeable contact lenses. However, primitive contact lenses were larger and supported by the sclera of the eye, rather than the cornea. In the 1930s and 1940s, there were rapid advances – first the lenses became transparent; next the thickness of the materials was reduced to around 0.4 mm. But after the end of the Second World War, O. Wichterle, a Czech chemist, realized that hydrogels were perfect materials for manufacturing contact lenses – they were more tolerated, breathed better and caused less allergic reactions. In 1952, his findings ended up spawning a new era of contact lens technology, all with the aim of correcting eyesight and reducing eye irritation.

If contact lenses were groundbreaking 50 years ago, the future is about bionic lenses – forget 20/20 vision; these lenses are designed to give humans 3 times what is today considered normal vision. Bionic lenses are implanted in a procedure rather like cataract surgery. The lens is injected into the eye where it unfolds into place. Such lenses would eliminate the need for many eye operations performed today. Developers of this technology are excited for the future as it guarantees super vision in all conditions, even underwater. The adaptive lenses are liquid filled lens compartments that function under water or in open space. The bionic lens is inserted into the eye and self-inflates to replace and occupy the same space as a traditional lens. The technology has been developed to use cameras with this technology so someone's bionic vision can be projected on a screen if that was desired. Garth Webb, a Canadian optometrist is the founder of iSYS Adaptive Optics Inc., developers of bionic eyes. He is excited about the future and is passionate about the potential. He sees 20/20 vision as a birthright of humankind.

But what about people that have damaged eye lenses but normal retinae and are therefore blind. Even bionic lenses would be difficult to implant if the tissues around were not adequate. Enter VRD (Virtual Retina Display), a technology developed by the Human Interface Technology Lab in Washington DC. VRD tries to mimic the working of a normal eye – in a normal eye, white light reflected from an object is reflected as colored light onto the retina, and certain rods and cones are selectively stimulated. Under VRD, the same rod and cone cells are activated using low intensity colored lasers that focus on the retina.

One thing is for certain, the future as not as we see it now.

Taste

> Whether you take the doughnut hole as a blank space or as an entity unto itself is a purely metaphysical question and does not affect the taste of the doughnut one bit. ~ Haruki Murakami in *A Wild Sheep Chase*

Why do we taste different foods as being sweet or bitter? How did taste buds evolve? This question has always fascinated scientists and foodies alike – and science went a long way towards answering this when remains of two women – one Neanderthal and the other Denisovan, were found in a cave in Siberia. These two groups were the descendants of modern humans. Genetic analyses of these women found genes for bitter taste receptors – two bitter taste receptors, TAS2R62 and TAS2R64 that we know mutated (and were inactivated) after chimpanzees and hominids diverged along the evolutionary path. Researchers found another 'bitter' gene, TAS2R38, that helps detect a compound called PTC, that is used to detect sensitivity to bitter tastes. We know that PTC (phenylthiocarbamide) has a chemical structure that resembles toxic alkaloids found in some poisonous plants. Therefore bitter tastes may have been a sensation developed to avoid people eating harmful foods. Interestingly, before modern humans split from Neanderthals and Denisovans (and indeed apes) another gene, MYH16 was deactivated. We know that this gene is linked to strong jaw muscles. Why would humans no longer need strong jaw muscles? We now know that this was when humans began to cook food, around 600,000 years ago.

In humans, sweetness is perceived, when sweeteners, either from natural foods or synthetic, interact with taste receptor proteins from the T1R family. Interestingly, cats cannot taste sweetness, unlike dogs. This is because, in cats TAS1R2 is an unexpressed pseudogene, and therefore functional sweet taste receptors like T1R cannot form, resulting in 'sweet blindness.' And while the origin of sweet taste is due to the fact that sugar provides calories, when man began walking more, it has also ended up a reflector of lifestyle. For example, we now know that having sweet genes and thereby a 'sweet tooth,' makes one more likely to drink more alcohol.

Taste buds therefore hold hidden clues to our ancestral diets. Within our tongues, tucked in crevices, hidden in corners, are many different kinds of taste buds. The tongue ends up like a biological bookcase, and taste buds are like books – arranged in different genres – sweet, salty, bitter, sour and umami. Umami? The fifth-taste is proof that our taste buds continue to evolve.

Just over a century ago, in 1908, a Japanese chemist at Tokyo University, Kikunae Ikeda noted that a widely used cooking-stock made from kombu (Japanese kelp) had a particular pungent taste he named unami. Massimo Bottura, a chef in Modena considers Parmesan cheese as the "most unami" ingredient. Other foods that are unami are aged cheeses, cured meats and certain mushrooms. And, of course, Marmite. When Marmite went out of stock in New Zealand due to a manufacturing problem, "Marmageddon"[3] struck New Zealand, with patrons cleaning out supermarket shelves to stockpile the local delicacy, and outrageous prices being asked by scalpers.

What was common to these was that this characteristic flavor is usually only produced by slow-cooking. Ikeda surmised that it was this longish cooking process that released the flavor – could umami be due to a chemical being released? This led to him eventually pinpointing glutamate, an amino acid, as the source of this culinary wonder. Interestingly, even human milk contains glutamates. Once Ikeda identified the chemical ingredient, manufacturers sought to include this in processed foods and now we have the widely used (and often controversial) ingredient MSG (monosodium glutamate).

The human race has become the fattest it has ever been. The World Health Organization (WHO) says world obesity rates have doubled since 1980.[4] According to the WHO, 39 % of adults aged 18 years and over were overweight in 2014, and 13 % were obese. In fact, today, more people die from being overweight, rather than being underweight. It may be no surprise then that with our increased consumption of fats, new taste buds have developed. Richard D. Mattes, distinguished professor of nutrition science at Purdue University has identified a new taste sense for fatty foods. When his team tested subjects, they found that people could distinguish 'fat' as a distinct taste sensation and one that may indeed be a warning system – fat is distinguishable, but in high concentrations tastes awful. However, in small quantities, fat is pleasant (think chocolate or potato chips) and reduces the feeling of fullness. Just as sugars do, fats also provide us calories and fat stores are essential during starvation. Processed food manufacturers have long exploited this knowledge – and packaged foods contain enough fat for you to want more, but not enough for you to taste pure fat.

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[3] Hannah Garrett-Walker. 'Marmageddon' sends NZ into a spin. New Zealand Herald newspaper, Tuesday Mar 20, 2012.

[4] Obesity and overweight. WHO. Fact sheet No311, Updated January 2015 http://www.who.int/mediacentre/factsheets/fs311/en/accessed Mar, 1 2016.

The future may be about newer synthetic foods entering the horizon and tricking our taste buds. We already know all the senses are linked, and therefore playing music one likes makes one feel a particular food tastes better. There is a fruit, *Synsepalum dulcificum*, sometimes called the 'miracle fruit.' It contains a chemical miraculin that primes taste buds to taste sweetness, but remains imperceptible until something acidic like a lemon or vinegar is tasted – the acidity triggers the sweet taste buds (after one has eaten the miracle fruit) and instead of tasting sourness, people taste sweetness. The future may indeed be in human beings similarly 'hacking' taste buds, but to what end?

Smell

> Each day has a color, a smell. ~ Chitra Banerjee Divakaruni, *The Mistress of Spices*

My primary specialty in medicine is in the field of skin cancer, and I have been fascinated by one of the latest advances in modern cancer research: a cancer-sniffing canine. Williams and Pembroke who first wrote an article in the journal, *Lancet*, about the dog's ability to sniff out a tumor felt that tumors such as melanoma emit unique odors due to their abnormal protein synthesis – these are undetectable to man, but not to dogs.

As people working in drug-detection or border patrol know, you can train a dog to detect the smell of almost anything. Dogs have around 220 million olfactory receptors in their noses, while humans have around 5 million smell receptors. It could be that the reduced number of receptors were to prevent humans from being too distracted or over-stimulated. Dogs also possess the vomeronasal organ, first described by Jacobson, that is separated from the olfactory receptors, and opens into both the nose and mouth – this is thought to be associated with 'social smells' such as pheromones and scents of other animals.

I met Margaret Atwood at the 2016 Jaipur Literature Festival in India recently. She and I were part of a group of writers invited to speak at the festival. Atwood was the star attraction at the Jaipur Literature Festival this year. We interacted after a session in which she spoke of the changing role of women in society, and I briefly brought up Aldous Huxley's *Brave New*

World,[5] a reprint she had written the foreword for, many years ago. She saw a world of 'soft totalitarianism' – hypnotic persuasion rather than brutality, wanton consumption feeding production lines at factories and of drugs that conferred biological bliss. Sadly, we agreed that the evidence for such was already all around us.

In her foreword, Atwood references similar dystopian novels like Orwell's *Nineteen Eighty-Four*, a book that gave us terms like Big Brother and a torture chamber called the Ministry of Love. Huxley didn't have a Ministry of Love in his novel, but he had a Scent Organ – "playing a delightfully refreshing Herbal Capriccio – rippling arpeggios of thyme and lavender of rosemary, basil, myrtle, tarragon …"

Can one artificially reproduce and transmit smells that would be recognizable and familiar to humans? Indeed moviemakers did attempt this with 'Smell-o-Vision' – in 1960, the movie *Scent of Mystery* was produced by Michael Todd Jr. (starring no less than Elizabeth Taylor). "First they moved (1895)! Then they talked (1927)! Now they smell (1960)!" exclaimed posters for this film. However, due to inadequate ventilation, patrons were exposed to a mush of different odors including tobacco, rose, wine, garlic, peppermint etc. The concept was abandoned because the cocktail proved too much for theatre audiences who panicked and suffered nausea.

The idea of transmitting smell was not abandoned altogether, however, and in June 1977, the BBC, on its *Reports Extra* segment demonstrated the 'Raman Spectroscope,' a device they said was capable of transmitting 'country smells' into viewer's living rooms. Many callers from Manchester, where the program aired, flooded the BBC with calls confirming that they could smell freshly mown grass or hay in their homes. Some even complained of hayfever!

More recently, Adrian David Cheok, who began his career in Adelaide, Australia, before moving to Japan and then Singapore's Mixed Reality Lab, has developed a device called the Scentee. This little device produces chemically-engineered smells at the touch of a button – click on coffee, chocolate, or any alcohol of your choice and the Scentee reproduces the smell chemically. Cheok says that the ultimate goal is not just to produce these smells in a store or at home, but to stream these perfumes online.

A Silicon Valley startup called Aromyx indeed has developed a biochip that has little wells that are linked to 400 different human odor receptor proteins – crazily you can blow aromas across the chip and the chip will demonstrate how each sensor reacts – in effect acting as an electronic nose. Avery Gilbert, an adviser to Aromyx feels that in 5 years, each smell would be coded and this e-nose would be as efficient (if not more) as a human nose. This may even have medical diagnostic uses, as in diseases like Alzheimer's, where the sense of smell is often the first indicator of the affliction. We could have devices sniffing out skin cancers such as melanomas.

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[5] Aldous Huxley, Brave New World, Chatto and Windus, 1932 (Reprint Vintage 2007) page vii.

Cheok sees a world where every physical thing and human will be connected to the internet. He sees a future where people making Skype calls could smell the other person, or their perfume, even if they were in different parts of the world. All this is technologically interesting and seems marginally useful to my primitive way of thinking. However, I must say I was alarmed when Cheok was quoted as saying ,[6] " I am currently collaborating with my friend David Levy, who wrote the book, *Love and Sex with Robots …*"

Hearing

> We hear only those questions for which we are in a position to find answers.
> ~ Friedrich Nietzsche

We know how changes in mobility brought about brain-size differences and how migration of humans caused different skin colors but the evolution of hearing from animal to man has not been as clear. Studies now show that when fossils of the ears of apes, Australopithecus (primitive man) and Homo (closer to modern man) are examined, the main differences is in cochlear length – the relative length of the cochlea and oval window structures of the ear are larger for body size as man evolved further – these indicate the development of low frequency sensitivity that is needed for language development. And this change happened around 2 million years ago.

In 1898, Miller Reece Hutchison developed the first hearing aid – this worked on the principle of a telephone and used electric current to amplify weak signals and therefore could only correct mild to moderate hearing loss. However, nowadays, cochlear implants are widely used as they are smaller, hidden easily in the ear canal and also more efficient – these cochlear implants can help severe hearing loss or damaged ears as they bypass damaged portions of the ear and directly stimulate the auditory nerve. These new cochlear hearing aids simply transmit impulses directly to the brain via the auditory nerve and the brain is able to decipher the signals as sound.

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[6] Robert Chalmers. Led by the Nose: The future of smell in a virtual world. Newsweek Insights, September 10, 2014. Kindle Edition, loc 569 of 707.

We know that speech sounds in all languages consist of consonants and vowels. Here's what is interesting – when vowels or consonants are replaced by just noise, listeners can still identify sentences without consonants but where vowels remain. But when results were analyzed electronically, researchers found that it was neither vowels nor consonants, but cochlear-entropy that matters i.e. ultimately it is not the sound, but the sensorial connection to neurons that matters. Which is why cochlear implants for people with deficient hearing have proved so successful.

The future for those with impaired hearing is getting better – a study on gerbils injected with stem cells showed that nearly half of the subjects improved their hearing. And, similar to contact lenses in the eye, an 'ear lens' has been developed – a device that is mounted on the ear drum and receives laser signals from an external part that sits behind the ear. The laser signals are then converted and transmitted as eardrum vibrations to replicate natural hearing.

It is often seen that sense organs seem to work synergistically – for example if someone loses eyesight, their hearing or touch is often more acute. I suppose all this comes down to quintessentially human concepts: feelings and sensations. Both centers of communication and contact interact with each other, and sometimes brazenly learn how to manufacture such things.

If ultimately what matters is the connection to neurons, then the location of the source should not matter. This mechanical engineering view is what allowed John Williams, associate professor in Colorado State University's Department of Mechanical Engineering to design a hearing aid that works via the tongue. It sounds bizarre, but after all a cochlear implant simply sends impulses to the nerve. Why could the tongue that already has many nerves not do the same? – As long as the tongue could recognize 'sounds.' This is what this device does – when pressed against the tongue it transmits sound waves as vibrations to the tongue. Researchers are getting better at 'training' the brain to interpret specific patterns as words, effectively turning tongues into ears.

The future seems to be about sensory (and indeed motor) substitution – allowing the brain to receive sensory signals via different sources, even from machines. Ultimately it doesn't seem to matter – getting signals to the brain is about getting the transmissions through correctly. All previous medical ways of looking at the human sensory system will soon be obsolete. The brain is after all a computer.

Touch

Touch has a memory. ~ John Keats

Aristotle was one of the first people to realize the uniqueness and the indispensability of the sense of touch for life. In *De Anima,*[7] he wrote about the sense of touch thus:

> Without touch there can be no other sense, and the organ of touch cannot consist of earth or of any other single element. It is evident, therefore, that the loss of this one sense alone must bring about the death of an animal. For as on the one hand nothing which is not an animal can have this sense, so on the other it is the only one which is indispensably necessary to what is an animal …All the other senses are necessary to animals, as we have said, not for their being, but for their well-being.

Aristotle summed up the sense of touch elegantly – the only sense essential for being (the others may be useful for well-being). This may be because skin and nerve cells develop at the same time and skin is our largest organ.

Interestingly new research shows the link between the sense of touch and hearing. Jeffrey M. Yau from Johns Hopkins University in Baltimore experimented with volunteers using headphones and fitted with vibratory pads at their fingertips. He found that ability to hear sounds varied depending on the pressure applied to fingertips. And, when Psychology professor Tony Ro from The City College of New York took this further and studied MRI scans, they noted 'synesthesia' a crossing over of senses and led him to conclude: "Not only do the two senses use similar processing mechanisms in the body and in the brain, but our results imply that hearing actually evolved out of the sense of touch."[8]

As more research focuses on neuronal connections and the connectivity between man and machine, it is clear that 'synesthesia' is real – we saw earlier how people could be taught to hear via the tongue, or hear via finger tips, recently researchers found that the music we listen to can affect our sense of taste – the music playing in the background tended to influence the notes written by wine-tasting students for example "powerful and heavy" (*Carmina Burana* by Orff), "subtle and refined" (*Waltz of the Flowers* from Tchaikovsky's "Nutcracker"), "zingy and refreshing" (*Just can't get Enough* by Nouvelle Vague), and "mellow and soft" (*Slow Breakdown* by Michael

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[7] Aristotle (c. 350 BC), translated by J. A. Smith, De Anima (On the Soul), An Internet resource developed by Christopher D. Green, York University, Toronto, Ontario, http://psychclassics.yorku.ca/. Aristotle/De-anima/, accessed 1 March 2016.

[8] Philip F. Schewe. 'Feeling' sound: The sense of hearing and touch may have evolved together. Medical Xpress. Neuroscience June 2, 2011.

Brook)[9] etc. Similarly, the taste of toffee was also dependent on how a person liked the music playing. Maybe that's why airline food tastes bad? Or there is hope for a bad cook (good music in the background).

This connectivity between senses is now termed "crossmodal correspondence" – our brains and/or minds tend to match features or dimensions across sensory modalities. As machines become more and more intelligent, "crossmodal correspondence" will move onto the next dimension. This may be future science's sardonic success – feeling without touching, hearing without ears and tasting without tongues, but as a member of the generation of last natural humans I am happy living in yesterday's world filled with imperfect eyesight and diminishing hearing. At least I can pretend to be deaf, sometimes.

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Chapter 12

Moving On

> Those who do not remember the past are condemned to repeat it.
> George Santayana

"Yes, me worry!"

The iconic motto, "What, me worry?" by Alfred E. Neuman, the fictitious mascot and cover boy of the American humor magazine *Mad*, was changed for one issue to "Yes, me worry!" after the Three Mile Island accident in 1979. When it comes to our current worldwide situation, I don't think we can ever go back to the pre-1979 laid-back stance of Neumann. The big question is if we will even survive, along with our non-human primate companions and all the other life on the planet, given the often abysmal actions of man.

When we describe the last *natural* man, a very curious problem arises. We have not really even come close to understanding what our full *nature* is, and now we are tinkering and tampering with parts of it without being able to foresee the outcome of our actions. Once again, I will tap the brains of others that have examined this problem and add in my own comments.

When it comes to the issue of survival, I can most readily relate to Matt Ridley in his book *The Rational Optimist: How Prosperity Evolves.* Ridley puts innovation on a pedestal as the key to ward off doom and gloom scenarios.

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He emphasizes that in our rapidly growing and continuously changing society, ideas need to meet and mate to create a cumulative, prosperous culture.

What inside of us helps us to continue our species? Is there a science of human nature that we can continually learn from as a method to practice "continuous quality improvement" in order to survive? One of the key premises of *The Tangled Wing* by Melvin Konner is that our biological makeup contains information about the environment that helps us resist disorder and achieve reproductive success. But there is more, much more, and as a noted anthropologist he combines biology and culture in a potent mix. Konner writes: "We must choose, and choose soon, either for or against the further evolution of the human spirit. It is for us, in the generation that turned the corner of the millennium, to apply whatever knowledge we have, in all humility but with all due speed, and to try to learn more as quickly as possible. It is for us, much more than for any previous generation, to become serious about the human future and to make choices that will be weighed not in a decade or a century but in the balances of geological time." (Konner, 2002: 488)

Religion and Evolution

Konner also provides his view on religion and evolution, a subject that must be tackled in any careful examination of the last natural man. Konner writes that, "Fewer than one in ten Americans accept evolution as a process that goes on without divine intervention. This book not only endorses the last view, it also claims that every aspect of the human spirit--mind, thought, feeling, love, dreams, hope, admiration, decency, faith, and in general everything that the religious person takes as evidence for the soul--came from that same natural process, without need of divine assistance." (Konner, 2002: xiii)

Konner invokes the power of the Science of Human Nature to account for the vast majority of what drives us. He evolved from a rigorous Jewish background, and I feel there may be times when he, along with many others from various faiths and walks of life, have looked inside their souls in deep meditation and outward at parts of creation and noticed at least some evidence of powerful, perhaps miraculous, transcendence. Charles Darwin published six editions of *On The Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life*, with variations in every edition (how unusual—change from Darwin!). Beginning with his second edition, in 1860, Darwin included the term "Creator" referring to divine assistance:

> Thus, from the war of nature, from famine and death, the most exalted object of which we are capable of conceiving, namely the production of higher animals directly follows. There is a grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved [stress added]. (Darwin, 1872: 669–670)

For a more in-depth examination of the subject, I refer you to read *War of the Worldviews—Where Science and Sprituality Meet—And Do Not* by Deepak Chopra and Leonard Mlodinow. I have used this book for several years to teach courses, and Chopra and Mlodinow present a stimulating and erudite back and forth on God, evolution, life, the cosmos, creation myths, and other stimulating subjects.

His Holiness The Dalai Lama wrote, "We need a worldview grounded in science that does not deny the richness of human nature and the validity of modes of knowing other than the scientific. If we can bring our spirituality, the richness and wholesomeness of our basic human values, to bear upon the course of science in human society, then the different approaches of science and spirituality will contribute together to the betterment of humanity."

Stephen King, whose novel *Revival* features a Methodist minister who condemns his faith after a horrific accident, has described organized religion as "a very dangerous tool that's been misused by a lot of people" during an interview in the Rolling Stone. He stated he "grew up in a Methodist church", but how he "had doubts" about organized religion ever since he was a child, and how "once I got through high school, that was it for me". However, the bestselling novelist chooses to believe in God "because it makes things better. You have a meditation point, a source of strength," he said. "I choose to believe that God exists, and therefore I can say, 'God, I can't do this by myself. Help me not to take a drink today. Help me not to take a drug today.' And that works fine for me."

King stated that he believed "in evil", but that all his life he has "gone back and forth about whether or not there's an outside evil, whether or not there's a force in the world that really wants to destroy us, from the inside out, individually and collectively. Or whether it all comes from inside and that it's all part of genetics and environment. He later states, "Evil is inside us. The older I get, the less I think there's some sort of outside devilish influence; it comes from people. And unless we're able to address that issue, sooner or later, we'll f****** kill ourselves."

Robert M. Sapolsky, the noted neuroscience professor, wrote, "I love science, and it pains me to think that so many are terrified of the subject or feel that choosing science means you cannot also choose compassion, or the arts, or be awed by nature. Science is not meant to cure us of mystery, but to reinvent and reinvigorate it." He also wrote, "If a rat is a good model for your emotional life, you're in big trouble."

The lyrics of Bob Dylan's song "Gotta Serve Somebody" includes

> Well, it may be the devil or it may be the Lord
> But you're gonna have to serve somebody

The lyrics' imperative reflect the words of the bible and the Covenant between the Lord and His People: If the duties of the law are fulfilled, "I will take sickness away from the mist of you." (Exodus 23:25). If they are violated, "I will point over you sudden terror, consumption, and fever that waste the eyes and cause life to pine away." (Leviticus 26:16)

In overview, there seems to be little room in this approach for human intervention, and it certainly appears to be a fatalistic approach with disease being a visitation from the Lord which had to be suffered. If you could act in full accordance with the law, you would have a perfect life and live above nature's law.

However, the accounts of sickness and intervention heavily populate the Bible's pages, and clearly there was never prohibition on healing. The Bible is filled with prophets that act as intermediaries between the divine and fellow humans, including healers such as Elijah, Elisha, Isaiah and the Nazarene preacher and his disciples. Daily prayers today are filled with the asking for divine sanctions on human healing. The healing arts still make progress, now at a blistering pace, among the most pious and the least reverent of humans.

Good vs. Evil

As Stephen Pinker writes in *The Better Angels of Our Nature*, the most popular symbol in the world reflects one of the most horrific torture devices used by mankind; over 500,000 people were murdered by crucifixion. And the most famous and terrifying crucifixion was reported to be redemption for us to be saved from eternal Hell, a narrative that is, so far, unproven. The homicidal and genocidal actions mentioned in the Hebrew Bible from Samson to David also point to a glorification of extreme violence throughout our history.

Yet for some unknown reason certain scholars attempt to point out a type of silver lining in the often morbid stories. Perhaps these stories were used for instilling some type of justice before there were any widespread court systems, the cautionary tales feeding the minds of young children with morals and dogma to prevent disobedience. Of course, tales of redemption and Hell still fill the meeting rooms and sanctuaries of churches everywhere and show little sign of diminishing.

I recently spoke at a memorial service for the Holocaust at the University of Tampa. A survivor named Mary started the program and did a tremendous job of bringing her dark time in a concentration camp to the light of a college campus. Mary was 15 years old when she was put into a ghetto and at 17 years old forced to live in a concentration camp. “The smell of death was everywhere,” she said.

And yet even among the Nazis, Mary said, “there were humans.” Her idea of “humans” contains a sense of humanity, even if only for brief moments in time, perhaps by only one of the thousands of the perpetrators of mass genocide. One of the soldiers left a little bit of food every afternoon in a corner of the camp and told Mary, “You have not seen me and you do not look in my direction.”

When she was finally released when she was 20, she said that “after being liberated, soon after I had to face the awful truth. I was the only survivor.” All of her immediate family had been murdered by the Nazis. Mary was a war orphan and forever and indelibly devastated by the tragic events of her early life.

When it was my turn to give an overview of the Holocaust, I looked at the dozens of young faces in the crowd. Almost all of the students sat quietly and absorbed the talk. I tried to cover the key events of the time and emphasized how Hitler and others had started as early as 1920 and before to set the stage for the eventual Holocaust. I hoped that certain factors gained purchase in their minds and would keep the memory of the Holocaust alive and fertilize a bit of increased tolerance. Every telling of this devastating story is an opportunity for a new beginning of awareness and offers a prayer that the enormous tragedy will not happen again.

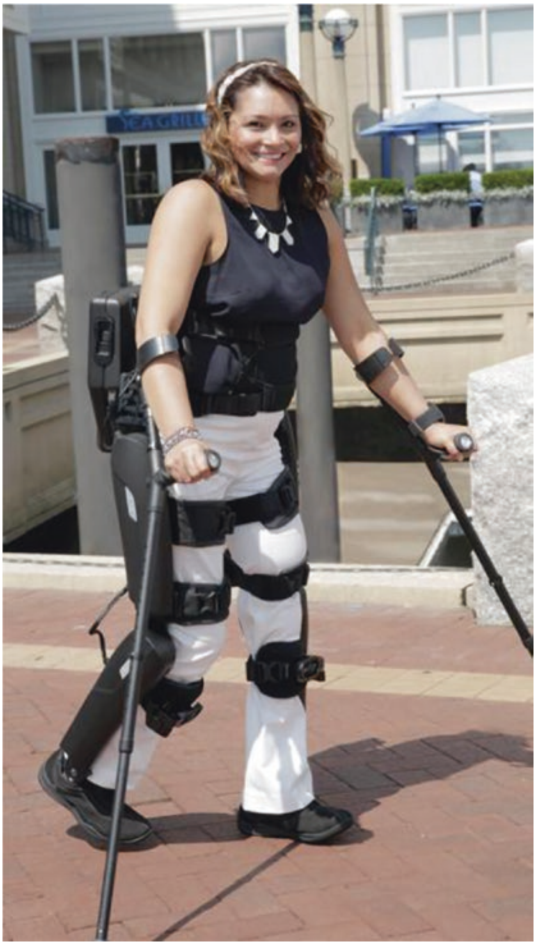
Technology

Walking into the ReWalk headquarter Yokneam Ilit, Israel, I had little understanding of what I was to experience and how much it would change my world. When I was in medical school, I had spent 6 weeks in training at the Rehabilitation Institute of Chicago and remembered the intense struggles and depression of those that had lost the use of their lower extremities due to severe spinal cord injury. No longer able to walk, the only option was the use of wheelchairs for mobility.

We were touring on the first Doctors for Israel mission (part of the Jewish National Fund), of which I am the national chairman. Included were physicians in different specialties from all over the United States along with their family members. As I looked around, I noted the amazed expressions on the faces of my colleagues and friends.

A middle–aged man in a wheelchair volunteered to demonstrate for our group. He was a dark haired man with stocky features, and rose from his wheelchair to balance on the ReWalk exoskeleton. Each of us looked on with great anticipation. He gracefully lifted himself and strapped himself in. Within a few moments he was walking. I thought I was on a science fiction movie set.

Think about it. Put yourself in the situation of someone with a profound disability that results in lower extremity paralysis. You will probably experience depression and a vastly lower quality of life than in your previous life. Of course, you will probably have a strong desire to walk again and be eye to eye with peers in social interactions. Your wheelchair allows only limited community access and inhibits meaningful social roles in the community. And then you find out about a new technology called robotic exoskeletons that would allow you and others with spinal cord injury to walk. **http://rewalk.com/rewalk-personal-3**



The ReWalk Rehabilitation model currently is used by patients in rehab centers all over the world. ReWalk is a wearable robotic exoskeleton that provides powered hip and knee motion to enable individuals with spinal cord injury. Sensors in the device detect subtle shifts in the user's center of gravity and upper-body movements and automatically translate these shifts into movement of its motorized leg joints. The ReWalk device allows the user to stand upright, walk, turn, and climb and descend stairs. The new model—the Personal 6.0--is worn outside the clothing and is attached to the user via leg braces and a harness and provides a more precise custom-fit system. In addition to the ability to stand and walk independently, clinical studies of the ReWalk Rehabilitation system show significant potential physiological benefits. It is the only FDA cleared exoskeleton for rehabilitation and personal use in the United States and is the most used and studied exoskeleton technology of its kind, with hundreds of ReWalkers worldwide.

Often we think of technological advances in terms of our cellphones, computers, and enhanced TV and media accessibility, and these clearly have come a long way since my early days when I would have to manually change the dial on my TV to get one of three stations. I watched eagerly as a young teenager on a hot Michigan day on July 20, 1969 as we landed a man on the moon, and that first step set the stage for even greater expectations.

During those teenage years, one of my teachers asked me what I wanted to do when I grew up, and I said I wanted to be physician and a writer. After 36 books and 34 years of medical practice I have proved myself an honest man. I take pride in the fact that my dozen medical books have been disseminated throughout the world and tens of thousands of downloads can now be readily accessed by providers eager to provide quality care to their patients. The advances in technology has accompanied me on my journey, along with all of my contemporaries, and helped save the lives of untold numbers of our fellow brothers and sisters.

The horrors of the AIDs epidemic has paralleled my years in medicine, and I have seen its chronology going from an awful percentage of fatalities, to those barely surviving on dozens of drugs and emergency interventions, to the onset of AIDS as a chronic disease. During this last week I saw at least 15 AIDs patients that are now thriving with only one drug for treatment, and the word on the street is that a vaccination may happen soon. And in the vast arena of medicine, devices like the ReWalk and thousands of other amazing inventions allow clinicians like myself, the jockeys of research, to help our patients to dream once again.

What about population growth and the promise of technology to help save us? Erle Ellis, professor of geography and environmental systems, wrote a compelling essay about the problem of overpopulation in response to certain scientists declaring that "Disaster looms as humans exceed the Earth's natural carrying capacity." Ellis wrote that "these claims demonstrate a profound misunderstanding of the ecology of human systems. The conditions that sustain humanity are not natural and never have been. Since prehistory, human populations have used technologies and engineered ecosystems to sustain populations well beyond the capabilities of unaltered 'natural' ecosystems."

Ellis points to the archaeological records and how our genus Homo predecessors used "social hunting strategies and tools of stone and fire to extract more sustenance from landscapes" than was offered by often bleak scenarios. Ellis points out that the rise of agriculture "enabled even greater population growth requiring ever more intensive land-use practices to gain more sustenance from the same old land. At their peak, those agricultural systems might have sustained as many as three billion people in poverty on near-vegetarian diets."

As Ellis notes, the Food and Agriculture Organization of the United Nations has estimated that the more than nine billion people expected by 2050 as the population nears its peak could be supported as long as necessary investments in infrastructure and conducive trade, anti-poverty and food security policies are in place. He writes, "The important message from these rough numbers should be clear. There really is no such thing as a human carrying capacity."

Ellis reflects that the science of human sustenance is inherently a social science and that "Neither physics nor chemistry nor even biology is adequate to understand how it has been possible for one species to reshape both its own future and the destiny of an entire planet. This is the science of the Anthropocene. The idea that humans must live within the natural environmental limits of our planet denies the realities of our entire history, and most likely the future."

All in all, Ellis matches the optimism of Ridley and echoes our need to rely on inventiveness and innovation. "Humans are niche creators," Ellis writes. "We transform ecosystems to sustain ourselves. This is what we do and have always done. Our planet's human-carrying capacity emerges from the capabilities of our social systems and our technologies more than from any environmental limits."

Ellis continues, "Two hundred thousand years ago we started down this path. The planet will never be the same. It is time for all of us to wake up to the limits we really face: the social and technological systems that sustain us need improvement. There is no environmental reason for people to go hungry now or in the future. There is no need to use any more land to sustain humanity — increasing land productivity using existing technologies can boost global supplies and even leave more land for nature — a goal that is both more popular and more possible than ever."

Ellis concludes that "The only limits to creating a planet that future generations will be proud of are our imaginations and our social systems. In moving toward a better Anthropocene, the environment will be what we make it."

++Overpopulation Is Not the Problem by Erle C. Ellis Sept 13, 2013 NY Times Op-Ed

Summary

Our minds are crowded to overflowing with aphorisms and analogies, and at least some of us try to put together a rational picture of the world. We are drowning in bits and bytes of information but starving for wisdom. In other words, most of us don't have a clue why we are here or what we are doing, but we plow ahead in the darkness of our lives and seek a nourishing light. As Thoreau said, "Most men lead lives of quiet desperation and go to the grave with the song still in them." (Civil Disobedience and Other Essays) But he also wrote, "Rather than love, than money, than fame, give me truth." (Walden)

We look for truth in the revolutionary science of chaos and the abstract nature of nonlinear dynamics, and out into the black holes of space. And for whatever reason, we are curious beyond survival and never give up on the quest for truth, checking in every unlit corner for a secret that unlocks another door in life's mysteries. We have been provided amazing gifts and opportunities and have incredible decisions to make in the future, many of which will be to decide which of our inherent strengths and weaknesses need to be amped up and which ones need the volume turned down. The Last Natural Man may be greatly missed some day, but the revised man of the future may be just what it takes to survive and thrive.

Chapter 13

The Last Chapter

> Extinction is the rule. Survival is the exception.
> “Carl Sagan, *The Varieties of Scientific Experience: A Personal View of the Search for God”*

We’ve been discussing how man is in his final incarnation as a natural being. What is natural after all? “Nature” derives from the translation of the Greek work, “Physis.” Indeed, from this word derives “Physics” but translations from the original Greek work include ‘nature’ and ‘essence.’ Plato wondered if all things must eventually be swallowed up in death. Is that the same for both man as a being, and humans as a species?

When man left Africa 100,000 years ago, he had a small footprint and what humans did to the planet barely affected other species. The growth of human populations has proceeded at an alarming and irresponsible rate. The chart below shows the world population growing exponentially and tripling over the last 1000 years – bringing with it demand for food, housing and environmental damage. Technology may be changing even when it comes to human reproduction, but the end result is the same as we have now: overpopulation (Fig. 13.1).

One fallacy that has developed over time has been human feeling of superiority over other species. After all, aren’t we the intelligent ones? What is intelligence? Cockroaches and bacteria were around to see the dinosaurs and have survived to the present day – that makes them vastly more successful than humans when if comes to survival. Chomsky, in his book “Hegemony or Survival”[1] observes that many species have come and

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[1] N. Chomsky, Hegemony or Survival: America’s Quest for Global Dominance, Henry Holt and Company, New York, 2004, pp. 1–12.

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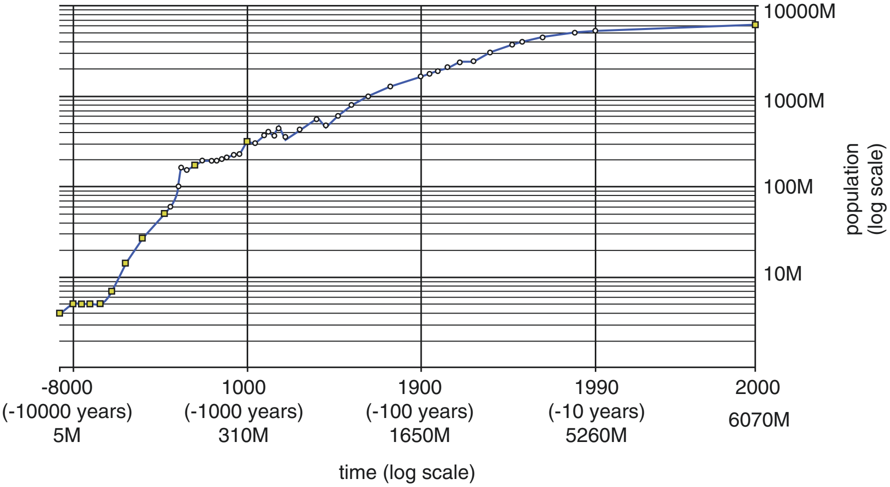

Fig. 13.1 World Population Growth. From By Waldir [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

gone – and in general, 'the average life expectancy of a species is about 100,000 years.' It is sobering that modern humans left Africa 100,000 years ago but have we been intelligent enough to learn the lessons from past extinctions?

Human history, even if recent in the grand scheme of things does not bode well – we have uniquely fought wars to kill others in our species when not hungry, burned fossil fuels and caused global warming. Our preparedness is geared towards military domination of others in our species, but not for the inevitable battle for survival of our species. 'Anticipatory self-defense' was a term coined by the historian Arthur Schlesinger, when he wrote about President George W. Bush's policies after the Iraq war began.[2] Humans may measure intelligence quotients and speak of emotional or financial intelligence but have we got the intelligence to be sustainable? Creatures like bacteria that have lived for 250 million years possess an archaic memory that involves the whole macrocosm of nature, a type of sustainable memory that involves consideration for the world around us. If we stop to think about it existentially, survival is the only thing that matters and that comes with a responsibility to control our vast urges that act selfishly in our individual interests. We all have to make do with this planet, this desolation within the universe, an exile of communicative beings. That's how any creature ended up having any history worth writing about.

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[2] Arthur Schlesinger, Los Angeles Times, 23 March 2003.

Not by consuming resources daily at such an alarming rate as if there was a bottomless pit somewhere.

Stephen Hawking, probably the world's best-known scientist, posed this question[3] a decade ago, when discussing his book, A *Brief History of Time*: "In a world that is in chaos politically, socially and environmentally, how can the human race sustain another 100 years?" Hawking wasn't being an alarmist, just asking an increasingly realistic question. Many scientists fear that not talking about the threat of human extinction only encourages us to be dismissive of the danger. Martin Rees, Britain's most distinguished theoretical astrophysicist has written the book, *Our Final Century: Will the Human Race Survive the Twenty-First Century?* (Heinemann, 2003) in which he calculates the probability of humanity surviving the next century at only 50 %. Rees believes that the human race, as we know it, can end due to an act of willful destruction. He feels that biotechnology and nanotechnology will enable greater destructive acts, and such weapons are easily concealed – Rees has even offered a $1000 wager that a terrorist act will result in a death toll of a million or more within the next 20 years. John Leslie,[4] has calculated the probability of human extinction within the next century at 30 %. Yet as individuals we worry about terrorist threats and how to keep out refugees but we have stopped thinking about humanity as a whole – and less so than other species that we consider lesser than ourselves. Given this, is there no way out of this doomsday scenario? As P.D James wrote in *The Children of Men*:

> Of the four billion life forms which have existed on this planet, three billion, nine hundred and sixty million are now extinct. We don't know why. Some by wanton extinction, some through natural catastrophe, some destroyed by meteorites and asteroids. In the light of these mass extinctions it really does seem unreasonable to suppose that Homo sapiens should be exempt. Our species will have been one of the shortest-lived of all, a mere blink, you may say, in the eye of time."

In her recent book, *The Sixth Extinction: An Unnatural History* (Henry Holt, 2014), Elizabeth Kolbert travels the world to document the mass extinction of many species that is occurring right now. Mass extinctions have happened before, and will happen again. The problem with such large-scale loss of life is that it takes millions of years to recover. The Earth is aware of this, and perhaps happy at the thought of being rid of its marauders – "Run, creatures run. Run into the burning fossil fires you created." – and after this the Earth goes back into its noble duty of nurturing life as if there was no end to this cycle.

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[3] S. Hawking, Re: Question on Yahoo Public, 2006 Available: http://answers.yahoo.com/question/index?qid=20060704195516AAnrdOD (A Brief History of Time. Bantom Books (1988).

[4] John Leslie. The End of the World: The Science and Ethics of Human Extinction. Routledge, London (1996).

Previously, people believed that creatures were created by God and therefore were manufactured for all eternity – and if a fossil was discovered, it only meant that the creature was somewhere in the world, hiding, or waiting to be discovered. Thomas Jefferson, once wrote[5]: "Such is the economy of nature that no instance can be produced, of her having permitted any one race of her animals to become extinct; of her having formed any link in her great work so weak as to be broken."

Darwin, however realized that extinction of species was real. As a scientist he often studied islands – and one who's name is forever linked to the Galapagos archipelago – and in *The Origin of Species*,[6] he wrote:

> So profound is our ignorance, and so high our presumption, that we marvel when we hear of the extinction of an organic being; and as we do not see the cause, we invoke cataclysms to desolate the world.

Darwin perhaps realized this because he spent a lot of time on various islands. In my book, *Skin, a Biography* (4th Estate, 2013) I quoted Charles Bennett[7] on the role of islands as evolutionary laboratories:

> Islands exert a special lure for men, and few among us have not at times allowed our thoughts to sail, like a windjammer in the trades, to make landfalls on fabled islands in distant waters.
> They are evolutionary laboratories where the evidence for organic evolution is often more apparent than it is on continents.

On an island it is easy to study mass extinction of species as there are less places for creatures to hide from catastrophic events. In New Zealand, where I have a home, Māori people arrived around 800 years ago to this uninhabited, and geologically young island. The Māori were welcomed by eleven moa species – gigantic ostrich-like birds – but within a few centuries there were no moa left – thousands of moa bones have been found at Māori archeological sites and they were likely hunted to extinction. The moa was a large bird and the larger a creature, the higher the risk of disappearance. Whenever humans arrived on an island, they caused species to disappear. 50,000 years ago, Australia was home to kangaroos, except unlike today's beasts – which are still large and make a handy kangaroo-tail soup.

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[5] Thomas Jefferson, quoted by Elizabeth Kolbert. The Sixth Extinction? The New Yorker, MAY 25, 2009 Issue.

[6] Charles Darwin, On the Origin of Species. 1859.

[7] Charles R. Bennett, in his review of Island Life: A Natural History of the Islands of the World by Sherwin Carlquist, published for the American Museum of Natural History [by] the Natural History Press, 1965.

Short-faced kangaroos were around ten-feet tall. Imagine being dragged out of your insomnia one early morning by the din of these creatures hopping about.

Wherever we look this scenario has been repeated, especially on islands. Two thousand years ago, humans moved onto Madagascar and guess what? – all mammals weighing more than twenty pounds, like pygmy hippos and giant lemurs disappeared off the face of the island. And it is all not due to hunting. Farming, logging, building homes, clearing paths or roads – all have an impact of the ecosystem. Richard Dawkins speaks of the extended phenotype – in his gene-centric view of the world, Dawkins suggests that our actions that impact the environment also impact the genes of parasites and other creatures distant from the host. The central theme of the book, *The Extended phenotype*[8] is: An animal's behavior tends to maximize the survival of the genes "for" that behaviour, whether or not those genes happen to be in the body of the particular animal performing it or not.

One-way of understanding this is using the 'rivet hypothesis- – this suggests that different species within an ecosystem are like rivets on an aircraft. You can only lose so many before there is a crash.

There have been many reports recently about frogs going extinct. Amphibians, like frogs are considered 'ecological indicators' – because these creatures are extremely vulnerable to climate or environmental change. And, frogs particularly have been long used by man – as good luck symbols in certain cultures, for scientific research and of course for food – The Food and Agriculture Organization of the United Nations estimated the average quantity of frog legs sold for human consumption to be just below 5000 metric tons per year. Frogs ended up as human pregnancy kits in the early days. Lancelot Thomas Hogben designed such a test called the 'Bufo Test' as it first used a toad of the genus *Bufo.* Essentially you injected a female frog with urine or serum of the patient. If the frog produced eggs within 24 h, the test was positive. This test was still being used in the 1950s until hormonal tests arrived in the 1960s. Interestingly, human contact has been devastating for frogs, as many species are ravaged by a chytrid fungus called *Batrachochytrium dendrobatidis*—batrachos is Greek for "frog"—or Bd for short. Bd seems unstoppable as a pathogen – it has crossed the Panama Canal, reached islands like New Zealand and is widespread in the USA. Rick Speare, an Australian pathologist who identified Bd first, now believes this Bd fungus was transmitted around the world by medical clinics and doctors, after its origins in southern Africa. This vulnerability to a pathogen that is unstoppable is a lesson for humans. Are frogs the ecological canaries in a coal mine? Or are modern day humans merely frogs in a slowly boiling environmental soup?

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[8] Richard Dawkins (1989). The Extended Phenotype. Oxford: Oxford University Press. p. xiii.

This fungus, Bd, is particularly alarming – it has been named as the cause of extinction of over 100 frog species. Frogs have great importance ecologically and in medical research – they feed on disease-causing mosquitoes that are dangerous to humans; the first to feel the effects of climate change – a living litmus test; and, of course they have been used as food as humans and other predators like snakes. But introduction of a new species into a pre-existing food chain can cause chaos – in New Zealand, possums were introduced as people felt that there would be a market for their meat and fur – now these creatures have run amok causing the destruction of many native species. Ditto the cane toad in Australia. And because cane toads are poisonous, they are not eaten by normal predators of toads and frogs – leading to an over population. A few years ago, I walked at night at the Currumbin Wildlife Sanctuary in Queensland and cane toads were everywhere. You couldn't help squishing a few under your feet accidentally as the ground was literally lousy with them. However, studies on cane toads on Australia have shown that they can lead to a reduction in mosquito populations. In a study,[9] researchers found that the invasion of cane toads may have some benefits. In India, several people are looking into using frogs as biological defenders against several mosquito-borne diseases as tadpoles feed on mosquito larvae.

Species come and go regularly, yet our Earth remains forever. Therein lies a lesson. My friend Louise Leakey – of the Leakey family, legends of anthropology – digs for fossils in the Turkana Basin in Kenya. She began her fossil hunting as a child, alongside her grandfather and now is a well-known academic and excavator. Working on fossils gives us the realization that we may not be here forever. Louise reckons that many species have existed for so long that they may have considered themselves inextinguishable. Suddenly, they are gone and replaced by others. Overall, there is a simple message: when you look at that bigger picture, no one is indispensible; every species has a choice – either you change and adapt, or, as a species, you go extinct. And more than often the unexpected happens.

Dinosaurs ruled the world for 135 million years. These large carnivorous reptilian forms were everywhere – sea, air and land. Until large mosasaurs or ichthyosaurs died away, we could have never had large sharks or whales that exist today. So the cycle of life continues. Dinosaurs died out during a mass extinction event known as Cretaceous-tertiary extinction event, otherwise known as K-T, when more than half of all species on our planet perished. The finding of iridium, a metal that is rare on Earth, led scientists to conclude that it was perhaps collision by an extra-terrestrial object such as an asteroid or comet that caused this dying out. But the underlying scenario that unfolded was climate change – one that these creatures were not adapted for. You'd think by now that the risk of climate change is well known and a given – with all these global conferences about it. But skeptics don't realize that there is nothing special about our species. We have been around for less time than most other creatures. In a way, our human species has been endowed with or evolved with a phantom feeling of superiority – a thought so discontinuous and incongruous with scientific history that one almost expects extinction. Perhaps this is what drives us to look at other planets, now that we have screwed up our environment.

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[9] Hagman M, Shine R. Effects of invasive cane toads on Australian mosquitoes: does the dark cloud have a silver lining? *Biol Invasions* 2007; *9*: 445–52.

Last year, Stephen Hawking delivered an address at the Sydney Opera House. Except he wasn't there in person – in his place was a holographic image beamed from Cambridge University. Hawking doubts that humanity will be around for another 1000 years, unless we colonize other planets. Professor John Webb, the director and co-founder of the Big Questions Institute at the University of New South Wales, who helped arrange this lecture, had this to say[10]:

> He's worried about the future of the human race. You know, he thinks that human beings are, I suppose naturally aggressive, …That may have been useful at some point in the early history of humanity enabling us to find food and get a partner and things like that, but he thinks that aggression that remains with us today is now the thing that could well end up destroying us …I think he's put a time on it to make us realize we've got to take better control of what we're doing.

Ever since human beings evolved in Africa, and modern man arrived 200,000 years ago, there have been population limits imposed by disease outbreaks, damage by human conflict and destruction of our habitat. Through it all, our genes evolved – in some ways, just as environment shapes our genes, our genes shape our environments. One way of looking at this is to consider evolution as nature's ultimate tool, and natural selection as one of its filters. But this process burdened man with a larger brain, and this larger cortex brought with it certain complexities. Even today, governments encourage us in the pursuit of STEM studies – science, technology, engineering and math – the things that created improvements in microbiology and mass-manufactured food production. Until now, man's footprint on Earth was small. It had to be small, as man had to live in harmony with the environment because of food supply problems.

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[10] Professor John Webb quoted in "Humanity won't survive another 1,000 years unless it escapes Earth, physicist Stephen Hawking warns." ABC news. 28 April, 2015 http://www.abc.net.au/news/2015-04-27/hawking-says-humanity-will-not-survive-unless-it-escapes-earth/6425162 accessed May 1, 2016.

The advent of food technology and microbiology changed everything. Especially our own 'biotic potential'. Biotic potential is a term that denotes growth capacity of a particular population. In general, it is based on the following:

1. Reproductive lifespans – if humans had a finite reproductive lifespan that became smaller as women entered the workforce, this is now changing due to reproductive technology as we have seen earlier in this book.
2. Litter size – As I detailed in a previous book, *Skin, a Biography,*[11] humans in Africa developed darker skin to preserve folic acid that reduced birth defects. When people migrated into Europe, the lack of sun caused rickets among the dark-skinned, and rendered them infertile. Therefore there was a constant battle between these two vitamins that shaped not only our skin colors but also our populations. However, today, we have the ability to supplement vitamins and indeed manufacture them. If our lifestyles no long require mateship to mean communion between the male and female of our species, advances in fertility science now ensures a steady supply of manufactured humans.

On one hand we have the biotic potential of a species, on the other we have the carrying capacity of our home planet. All this manufacturing to feed and house our masses uses up natural resources. For example about 1000 tons of water are needed to produce 1 ton of grain. Almost 40 % of all grain is used in meat and poultry production.[12]

The mapping of our genome has opened up a vast new array of medical advances and treatments that have the potential to vastly increase human lifespans. This isn't fundamentally 'natural' and part of the reason why we are the last species of natural humans. It's like as a species, when we evolved, we knew our neighboring species and actually were forced to look out for them. Now, it is a case of wanton destruction, not with the courtesy of co-existence. If other creatures look at us today, they must wonder: Who are these people? What do they think they are doing?

Part of the reasons bacteria and viruses are becoming more and more dangerous to humans is that they haven't stopped evolving. The more we manufacture drugs, the more they evolve stronger. Today's technology has evolved so much that anyone can download a gene sequence for small pox or bird flu from the Internet. But as technology progresses and DNA synthesis machines evolve further, not only can man download these genetic information, he can also manufacture them. If previously we worried about some nutter running loose with nuclear weapons, we now have the real danger of biological warfare. Nick Bostrom is the director of the Future of Humanity Institute at Oxford. He explains the 'simulation argument' thus[13]:

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[11] Sharad P. Paul. Skin, a Biography. 4th estate, 2013.

[12] Population Size: What Population Can Earth Sustain. R.L. McConnell & Daniel C. Abel, Environmental Issues. Measuring, Analyzing and Evaluating. https://www.wou.edu/las/physci/ch371/lecture/popgrowth/carrying.htm accessed 1 May, 2016.

> …
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> 1. Almost all civilizations like ours go extinct before reaching technological maturity.
> 2. Almost all technologically mature civilizations lose interest in creating ancestor simulations: computer simulations detailed enough that the simulated minds within them would be conscious.
> 3. We're almost certainly living in a computer simulation.
>
> …
>
> First, the first of those three possibilities, that almost all civilizations like ours go extinct before reaching technological maturity obviously bears directly on how much existential risk we face. If proposition 1 is true then the obvious implication is that we will succumb to an existential catastrophe before reaching technological maturity. The other relationship with existential risk has to do with proposition 3: if we are living in a computer simulation then there are certain exotic ways in which we might experience an existential catastrophe which we wouldn't fear if we are living in basement level physical reality. The simulation could be shut off, for instance.

Herein lies the real problem. In my view, we may be creating artificial intelligence and attempting to colonize other planets, but what sustained humanity thus far was our vulnerability, not our strength. Artificial intelligence itself poses a real risk to humanity. We may be the creator of superior mechanized beings, but owe our survival to our anxiety not our intelligence. If you stop to think about it, the anxious genes survived as brave-hearts charged out of their caves to face saber-toothed cats, only to be consumed. It is our nurturing of fellowmen that sustained us, as we formed societies based on countries and colonies. The biggest challenge we face is this – it is all very well creating artificial intelligence and a new species of transhumans, but these new being are physically stronger and fundamentally unanxious, unemotional creatures.

I met Patch Adams at Uplift, a conference for human consciousness in Australia a few years ago. Adams is a doctor-clown whose medical work was immortalized on screen by the late Robin Williams. He began his lecture by "mooning" the audience. Then he had this to say: "If we don't change from a society that worships money and power to one that worships compassion and generosity, I think we'll be extinct by mid-century. I don't say that as an alarmist or as a pessimist."

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[13] Ross Anderson. "We're Underestimating the Risk of Human Extinction" The Atlantic magazine interview with Professor Nick Bostrom. March 6, 2012.

We've come a long way as last natural men. But during our long walk, the last natural footprint has become bigger and bigger, and it is no longer deft enough to avoid sinkholes of extinction. And the heat came with us, every step of our industrial way. They may have been a few shunned ones, eyes dimmed by their pursuit of humanitarian causes and creating world peace, all the while cognizant of the threat of extinction.

There may still be hope for the Last Natural Man. But it lies in the understanding that whatever the cause, it was ultimately climate change that caused every earlier major extinction. Bacteria and viruses can cause the downfall of our species, but they know better than to kill off their food chains. Smoke. Fire. Illness. We are in a room where the air-conditioning has become unpleasant. Throughout our reading of evolutionary history, we last natural humans have considered ourselves special, immune to the destruction that befell many larger and stronger species. The legacy of the last natural humans' final stand is in the lengthening shadow of our presence. If this has awakened us enough, it is not clear yet – we may live for billions of years, conquer diseases like malaria, our descendants may colonize other planets, and develop barriers against comets and asteroids – but the success or sustainability of a species is something that others study only after its demise. Francis of Assisi once said: "Start by doing what's necessary; then do what's possible; and suddenly you are doing the impossible." It's just that the Last Natural Man has always done things in the reverse order.

THE END

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Epilogue

> *Strange is our situation here on earth. Each of us comes for a short visit, not knowing why, yet sometimes seeming to a divine purpose. From the standpoint of daily life, however, there is one thing we do know: that we are here for the sake of others.*
>
> Albert Einstein

The above quote by Einstein is of the utmost importance as we move down our collective path. As Leonard Mlodinow pointed out in his book *Subliminal*, "social relationships are so important to humans that a lack of social connection constitutes a major risk factor for health, rivaling even the effects of cigarette smoking, high blood pressure, obesity, and lack of physical activity."

Despite all of the forces that seem to be stopping our progress in making our best decisions to prosper, including political stalemates, global warming, and uncontrolled greed, we consider this a time of hope and that the ideas set forth in our book can be, overall, quite optimistic. But the tough mission of reform and revision will not be accomplished if we do not all join forces to help. We are hoping we have presented a clear and engaging guidebook for navigating the often confusing and cloudy waters of the future of medicine and our life on Earth. Here we have covered some of the battles we need to face in order to survive and thrive in the world of globalization and the new Pangea. But it will take all of us, from every segment of society, to accomplish a winning future. E.O Wilson wrote "if the heuristic and analytic power of science can be joined with introspective creativity of the humanities, human existence will rise to an infinitely more productive and interesting meaning."

When it comes to transforming our inherent biology, we must clearly walk with trepidation in that direction. Wilson wrote "the stories that

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compose the conscious mind cannot be taken away from the mind's physical neurobiological system, which serves as script writer, director, and cast combined. The self, despite the illusion of its independence created in the scenarios, is part of the anatomy and physiology of the body." A cautionary tale, indeed. He writes about engineering our own genetic code in order to change our biology, enlarging our personal memory capacities and developing new emotions with the possibility of boundless new creativity to the sciences and the arts. Wilson's overall take on the subject seems to be that "it should not be done except for correcting disease-causing mutant genes." For the hundreds of thousands that deal daily with life-threatening and quality deteriorating diseases, perhaps these changes cannot come soon enough.

What about the brain, the mostly hidden wonder that demands so much of modern research? Wilson writes, "I believe it would be unnecessary for the species survival to retrofit the human brain and sensory system, and, in one basic sense at least, it would be suicidal. After we have made all of the cultural knowledge available with only a few keystrokes, and after we have built robots that can outthink and outperform us, both of which initiatives are already well underway, what will be left to humanity?" Wait, there's more. "There's only one answer: we will choose to retain the uniquely messy, self-contradictory, internally conflicted, endlessly creative human mind that exists today," Wilson writes. "That is a true Creation, the gift given us before we even recognized it as such or knew its meaning, before movable print and space travel."

What about disease, both acute and chronic? Who and what will be the barometer of what measures we need to take to protect us? Disease detection and transmission patterns, from Ebola to Alzheimer's, and establishing the etiological agents of the diseases, are crucial steps. But often we cannot wait for proof, and the entire history of epidemiology is filled with life-saving acts with only limited evidence. In 1854, John Snow, the "father" of modern epidemiology, met with the Board of Guardians of St. James's parish, on the evening of Thursday, 7th September, to have the Broad Street pump handle in London removed. He protected untold numbers of citizens from sickness and death from cholera, long before the acceptance of Vibrio cholera as the causal agent.

A certain type of human behavior characterized by reflex-like rejection of new knowledge has its own metaphor--The Semmelweis Reflex. When the entrenched beliefs, norms, or paradigms of a group appear to be blatantly contradicted, the psychological phenomena known as groupthink kicks into gear to minimize conflict and reach a consensus decision without critical evaluating alternative or dissenting viewpoints. The reflex is named after Dr. Ignaz Semmelweis, now recognized as a pioneer of antiseptic policy, who based his hand-washing suggestions on trained observation and insight. Being ridiculed and rejected by his contemporaries not only led to the demise of hundreds of innocent patients, but eventually to his own.

Robert A. Norman

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In a scene from 'Transparent,' Jill Soloway's television series that airs on Amazon, a character, Rabbi Raquel, says, "Please don't do this to me – betray me and then tell me it's a gift." As we enter the era of The Last Natural Man, with replaceable parts and reprogrammable machinery – the future seems uncertain, even if it looks both inevitable and irresistible. We've lived our entire lives avoiding certain foods, either due to religious superstition or scientific scaremongering – but you see, we are forgetting that we have evolved over billions of years; tiny little changes that have ensured the future of our species. And right now, things don't look so good. There is a story every child has heard – about footprints in the sand – when troubled times occur, there are only one set of footprints – irrespective of what you believe, whether God or Nature has carried you at times, in a technological future, the new gods seem to demand money first. We already live in an era of increasingly unaffordable healthcare? Is this technology a help or hindrance? And importantly, is it human?

On one hand, we can envisage a future filled with robots moving about in driverless cars, serving their nearly human masters, making questions like, 'What is a weekend?' or 'What work do you do?' redundant for most professions.

The questions and answers for 'The Last Natural Man' is in remembering what makes us natural – Nature – without biodiversity we are nothing. We have gobbled up resources like a glutton at a heavenly buffet, and now are looking to create colonies on other planets we can destroy. In my second novel, To Kill a Snow Dragonfly,[1] I wrote: *This something usually has to do with human distractions and of men trampling on the snow without noticing its beauty. In the beginning, such shallowness used to upset the snow, but now it simply accepts it as a strange facet of human behavior*.

We ignore Nature at out peril. We drown in information, while many places are parched with a lack of drinking water; in the future machines will be able to think critically, but can they think wisely … and for the good of the human race?

Recently neuroscientists and psychologists were amazed at the discovery of 'mirror neurons' – nerves that make us feel the pain of others and are implicated in things like 'phantom pain' when a limb is absent. Things like this give us empathy. It is connectedness and caring for one another that allowed human beings to end up the dominant species on Earth. And with that comes a responsibility. The Earth is our home and also the home for billions of other creatures, many small and defenseless. We owe the survival of our species to them – because our physiology derived from smaller creatures, our adaptation was not as brilliant as some others, but ended up passable. All biological species are linked. ‘Bios’ means life and ‘logy’ roughly translates to knowledge. To my fellow doctors, scientists and readers, I’d like to quote Martin Luther King Jr: “*There comes a time when one must take a position that is neither safe, nor politic, nor popular, but he must take it because conscience tells him it is right*.”

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[1] Sharad P. Paul, To Kill a Snow Dragonfly. Fourth Estate, 2013 page 24.

There is no point ending up ‘last natural men’ unless we last. Sustainability is everything. That’s what Nature has long strived for and we have to carry the torch: To do not what is more advanced, but what is more right. For us, and everyone else on this planet.

Sharad P. Paul